REPORT NO. DRXTH-FS-CR-80085

FINAL REPORT
FOR THE
FRANKFORD ARSENAL
DECONTAMINATION/CLEANUP PROGRAM

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NOTICE

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Frontispiece — The Frankford Arsenal, Philadelphia, PA

1. INTRODUCTION

The Frankford Arsenal dates back to 1816. During its 161 years of operation, a variety of activities including munitions manufacture, materials and research development activities, development of propellant and cartridge-actuated devices, and a variety of procurement missions were accomplished at the Arsenal. In 1976, the facility was declared excess to Army needs and plans were put in place for the decontamination and cleanup of the Arsenal prior to transfer of the property to the General Services Administration (GSA) for subsequent disposition and release for unrestricted use.

In the spring and summer of 1978, a survey of the 110-acre Arsenal was conducted by Battelle Columbus Laboratory under contract to the Department of the Army. This survey identified low levels of (1) heavy metals residues, (2) explosive residues, and (3) radiological contaminants. Based on the results of this survey, bids were requested from various industrial contractors to perform decontamination and cleanup of the Arsenal. In September 1979, a contract for the Arsenal decontamination and cleanup was awarded to the Energy Systems Group, Atomics International Division, of Rockwell International (hereafter referred to as Rockwell), located in Canoga Park, California.

The decontamination and cleanup program has been completed. The purpose of this report is to present a summary of the program and the results obtained. The detailed information and results, along with operating procedures, the various planning documents, and certification data, are presented in 99 backup reports (see the appendix), totaling nearly 4000 pages.

2. BACKGROUND

2.1 HISTORY OF THE ARSENAL*

Until the late 1700's, Indian encampments dominated the shores of what is known today as Frankford Creek. An Indian village on this creek was recorded on maps as early as 1654-55 and again 25 to 30 years later when Thomas Holme, a surveyor employed by William Penn, charted the region.

Along this area at that time was part of the grant owned jointly by Thomas Penn and his two sons, John and Richard. The Indians had free range of the land and frequently used the area for hunting and for their campgrounds. Throughout the years, during various stages of construction, numerous arrowheads and other Indian relics have been found throughout the Arsenal grounds.

Long before the Arsenal was established, the site was used for the storage of ordnance supplies remaining from the Revolutionary War. They were stored in a barn located in an area which is now the corner of Tacony and Bridge Streets.

At the beginning of the War of 1812, much of this material was sent to the battlefield. At war's end, however, even greater amounts of equipment were returned to the area, which was then known as the "Cantonment of Frankford Creek." In 1816, Frankford Arsenal was established under the general authority providing depots to be established in various parts of the country, as contained in Section 14 of the Act of Congress, February 8, 1815. Frankford Arsenal was the second of the nation's old line arsenals to be established. Watervliet Arsenal, Watervliet, New York, the first, was established in 1812.

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*This history is taken almost verbatim from the "Public Affairs Plan for Decontamination/Cleanup at Frankford Arsenal," published by the Department of the Army, January 25, 1980.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The decontamination/cleanup of Frankford Arsenal was conducted in three phases. During Phase I, verification tests were conducted to demonstrate the effectiveness of various decontamination and cleanup methods. Standing Operating Procedures (SOP's) required to conduct the decontamination/cleanup operations were prepared during Phase II. Actual decontamination/cleanup operations were conducted during Phase III. The decontamination/cleanup at

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Frankford Arsenal consisted of removing low level radiological contamination and heavy metals and explosive residues that resulted from the Arsenal's 161 years of operation. Buildings, sumps, and sewers contained heavy metal and explosive residues and rad contamination was present in buildings, sewers, sumps, vents and outside areas. These areas were decontaminated to meet established cleanness criteria so that the Arsenal could be released for unrestricted use. In addition, the 400 Area, used to manufacture primer mixes and pyrotechnic material, was demolished due to its history as an explosive manufacturing facility, and the low likelihood for reuse of the small structures in this area.

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On May 27, 1816, a plot of 20 acres and 34 perches was acquired by the Government for the establishment of Frankford Arsenal from one Frederick Farley and his wife, Catherine, for the sum of $7680.75. This tract of land was located at what is now the corner of Tacony and Bridge Streets, and it fronted on Frankford Creek, then a navigable stream leading to the Delaware River. The reasons stated for selecting this site were: "The superior facility and economy of water carriage, and the arrangement of the store-houses, magazines, laboratory and workshops such that in the event of fire or explosion a part only would be damaged or destroyed."

The Saturday Evening Post, dated April 7, 1832, published a wood cut of Frankford Arsenal and a brief caption which reported that the originally planned construction was completed in 1830. The caption said: "It consisted of six large and capacious stone buildings, and two small workshops, forming a square, besides a magazine and gun shop."

"This Arsenal is one of the principal depots for small arms, ammunition, etc. At this time it contains about two million flints, five hundred thousand pounds of refined nitre, and thirty-nine thousand stand of small arms, besides a large quantity of other military stores..."

In the following 161 years, this tiny cluster of sturdy brick and oak buildings — most of which are still standing — grew to 212 structures housing a wide variety of laboratories and complex manufacturing and support facilities.

Until the War with Mexico in 1846, the chief Arsenal activities were repair of artillery and infantry equipment, proving and testing musket and rifle powder, and general storage and distribution of ammunition and small arms, artillery, and cavalry equipment.

From the Mexican War to the Civil War, the Arsenal engaged mainly in storage, preservation and repair of ordnance stores, fabrication of small quantities of ammunition, and other miscellaneous items. The first power-driven machinery was introduced in March 1853.

During the Civil War, the Arsenal served as a depot, receiving, storing, inspecting, and distributing supplies of all kinds. Appreciable manufacturing, especially of percussion caps, bullets, cartridges and other small-arms ammunition items, required a wartime work force numbering 1550. After the war only 550 were retained.

Although early history of the Arsenal refers to a "Laboratory," laboratory work as it is known today began in 1864. In April of that year, after discussion with the du Pont Powder Company, Captain Theodore T. S. Laidley, the Arsenal's 17th commander, conducted experimental tests of the effect of powder explosions on iron framework buildings.

In 1865, center fire cartridges were developed, and in October 1866, manufacture began of cartridges cases for .50-caliber service ammunition.

The Laidley Laboratory was built in 1868. Testing powder submitted by commercial concerns was its main purpose. With the adoption of smokeless powder by European governments about 1892, Captain John Pitman was assigned to study this sensational development and organized a chemical laboratory. Powder standards were established with such striking success that in 1896, Captain B. W. Dunn, the inventor of an explosive known as "Dunnite," was appointed to organize a study of all types of explosives.

In the same year, Mr. W. J. Williams, a Welshman and a Fellow of the Royal Society, became the Arsenal's first chemist. (In July 1906, he was granted Patent No. 825,168 for progressive-burning smokeless powder, a development as sensational as smokeless powder itself.)

During the Spanish American War, the Arsenal's output expanded, with all departments working at least two shifts manufacturing small-arms ammunition, sights and instruments of all kinds, fuzes, primers, and shrapnel. Small-arms ammunition production averaged 37,000,000 rounds annually.

Pursuing the fundamental theory that "if you can't see 'em, you can't hit 'em," the development and manufacture of precision sighting instruments

was recognized as a major Arsenal activity as far back as 1894. For example, the panoramic sights for the 3-inch field gun were first assembled at the Arsenal in 1903. Since then, development of improved and telescopic sights continued. Consolidation of various related activities resulted in formation of the Instrument Department in 1910, which included an optical shop.

Research and development activities were carried on in laboratories well equipped for investigations in the fields of electronics, optics, mechanics, and materials testing. Pilot models of instruments were made in a model shop equipped for this purpose.

About 1903 it was realized that most of the world was dependent on Germany for optical glass and elements. To eliminate this condition, an optical manufacturing shop was established.

The Arsenal's Gage Department, which entailed the precise gaging of all ordnance materials, was founded in 1917.

The small-arms ammunition production during World War I consisted of .30- and .45-caliber types. The Arsenal also manufactured all .30-caliber tracer, incendiary, and armor-piercing ammunition for Army and Navy aircraft. From January 1917 through November 1918, 232 million rounds were produced.

Millions of rounds of artillery ammunition, including shrapnel and high explosives, were manufactured and loaded at Frankford and shipped to the European front. As production mounted, however, recurring explosions endangered neighborhood residents because the areas surrounding the Arsenal had become densely populated. Consequently, loading of primers was discontinued at the Arsenal and moved to lesser populated areas.

Production experience in World War I made it imperative that gages be designed to insure the interchangeability of all future manufactured material.

Frankford's gage mission was expanded in July 1923 to cover gage design and automatic, electronic, and pneumatic inspection equipment for all fire control material, small arms, and artillery ammunition.

In 1927, the acquisition of the Junghans fuze from Germany prompted experiments and development of the mechanical time fuze. Before World War II, Frankford Arsenal was the only manufacturer of mechanical time fuzes in the nation. In order to meet wartime needs, it was necessary to train industry in manufacturing techniques. In the meantime, Arsenal production of mechanical fuzes increased from 29,000 to more than 250,000 per month.

Mention must also be made of the Arsenal's electrical (VT) fuze activities during World War II. Experimental fuzes, both electromechanical and electronic, for missiles, rockets, and artillery were developed, debugged, and readied for industrial mass production. Of these, the proximity fuze was considered to be one of the most significant contributions to fire power during World War II.

Under a plan developed in 1936, the Arsenal began using automatic machinery, and production layouts were rearranged on a straight-line basis. These changes revolutionized shell manufacturing, and production in most instances was doubled. Draw press operations for small- and medium-caliber operations were also speeded up.

During World War II much emphasis was devoted to .50-caliber ammunition; however, a new .60-caliber ammunition was developed and tested, pilot production lines were set up, and approximately 1.3 billion rounds were produced from January 1942 through August 1945. In addition, many new experimental and miscellaneous types of ammunition were developed and proof tested.

Throughout the war, Frankford Arsenal was heavily involved in research, development, and production of fire control instruments, small-arms ammunition, and artillery shell and cartridge cases. Small-arms production increased to a rate of 8 million rounds per day, or more than 2.5 billion rounds per year.

At the height of World War II, more than 22,000 persons were employed at Frankford. At war's end, this figure was reduced to 6850.

During the post-war years, the Arsenal's mission was changed drastically and was practically limited to research and development. As in previous wars, however, Frankford Arsenal had key roles in the small-caliber ammunition buildup required to meet the demands of war in Korea and Vietnam.

The closure of Frankford Arsenal on September 30, 1977 was an integral part of the Department of the Army's Project Concise, a 2-year, worldwide realignment program to improve management, fully exploit available technology and resources, and reduce operating costs. The closure of Frankford was related to the transfer of mission-related functions to the newly established Armament Research Development Command (ARRADCOM) at Dover, New Jersey; the Army Armament Material Readiness Command (ARRCOM), Rock Island, Illinois; and other Army Material Development & Readiness Command (DARCOM), and Department of Defense Organizations.

In June of 1977, the office of the project manager for Chemical Demilitarization and Installation Restoration (now the U.S. Army Toxic & Hazardous Materials Agency, USATHAMA) assumed technical direction for the decontamination and cleanup of the Frankford Arsenal. The major objectives of the decontamination and cleanup were:

- To conduct a comprehensive survey of Frankford to determine the quantitative and qualitative degree of contamination
- To establish the economic alternatives for decontamination based on the results of that survey
- To evaluate methods and equipment required for decontamination
- To conduct decontamination and cleanup operations in accordance with the requirements of the Federal Property Administration Services Act for property turnover to the General Services Administration for disposition.

As the first step in the Frankford program, a records search was conducted by USATHAMA during June-July 1977. The records search revealed several areas of concern, including low-level radiologically contaminated buildings

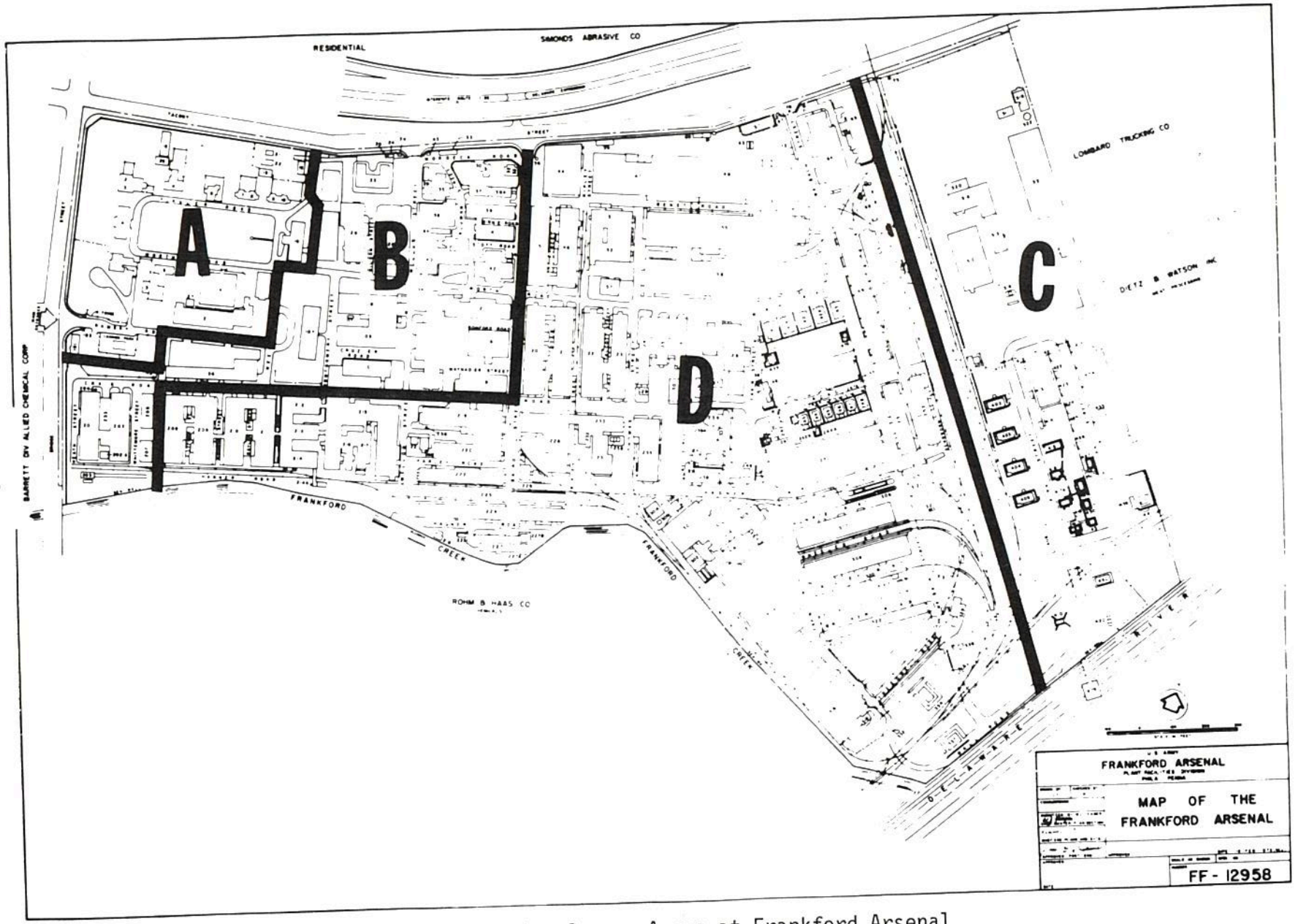

Figure 1. Survey Areas at Frankford Arsenal

and their related ventilation systems; deposits of explosive/pyrotechnic residues in buildings and their ancillary support systems, unknown quantities of subsurface and underwater unexploded ordnance, and organic and inorganic chemical residues throughout a number of buildings and their ancillary support systems.

Of particular concern was the underground waste discharge system which includes sumps, traps, and drain lines that were suspected of containing explosive/pyrotechnic materials.

The Department of the Army approved the in-house/contractor approach in October 1977 and authorized funds for the survey and assessment phase of the decontamination project.

The Arsenal was divided into four physical areas (A,B,C, and D) for the survey (see figure 1).

Area "A," a 10-acre tract located in the westernmost corner bordering Bridge and Tacony Streets, consists of 26 buildings.

An evaluation of this area, consisting of a visual and instrumental survey by an in-house (DOD) technical team, was completed in November 1977. No evidence of contamination was found and, as a result, area "A" has been certified for release.

Area "B," which borders a portion of Tacony and Bridge Streets and Frankford Creek, consists of 46 multipurpose buildings.

An evaluation of area "B," conducted by the DOD technical team,was completed in December 1977. As a result of this evaluation, 26 buildings and about 16.5 acres of land were certified for release.

However, 16 buildings plus the sewer system were not certified for release because of the potential for radiological contamination and heavy metal

deposits. These 16 buildings and sewers were resurveyed, and low-level contamination was confirmed in only one building and its sumps and sewers. Heavy metal residues were detected in all 16 buildings.

The technical team that conducted the evaluation of areas "A" and "B" consisted of representatives from the Army's Armament Research and Development Command, Dover, NJ; Philadelphia District, Corps of Engineers; Naval Explosive Ordnance Disposal Facility, Indianhead, MD; and Naval Underwater Ordnance Disposal Unit, Ft. Story, VA.

Also participating were representatives from the Army Environmental Hygiene Agency (AEHA), the Ballistic Research Laboratory (BRL), and the Army Toxic and Hazardous Materials Agency (USATHAMA), all from Aberdeen Proving Ground, MD.

In March 1978, USATHAMA awarded a contract to Battelle Columbus Laboratories of Columbus, Ohio, for a 5-month study to confirm or deny the presence of contamination at Frankford Arsenal and to develop alternatives for decontamination, if required.

The contractor's final report was received in November 1978, and the Philadelphia Industrial Corporation was briefed on the results of the contamination survey.

Following an evaluation of the suggested decontamination alternatives and cost validation, in February 1979 the Department of the Army approved the recommendation to clean up the Arsenal for unrestricted use.

After that decision was made, USATHAMA then proceeded with the necessary administrative procedures to award a contract for the required decontamination and cleanup.

In the March 20, 1979 issue of Commerce Business Daily, the Army announced that it was seeking qualified sources from private industry for a three-phase contract to perform the decontamination and cleanup of FFA.

Qualified sources had 10 days to reply to the solicitation notice. Requests for quotations from responding firms were sent in May 1979.

On September 21, 1979, a $6.3 million contract was awarded to Rockwell. The 17-month contract called for a three-phase, on-site decontamination and cleanup program with closeout documentation to be completed in February 1981.

2.2 DECONTAMINATION AND CLEANUP PROGRAM

The decontamination and cleanup program was organized in three phases, specifically:

- Phase I, which was used to demonstrate the effectiveness of various decontamination and cleanup methods
- Phase II, the generation of standing operating procedures required to control and direct the phase III operations
- Phase III, the actual decontamination and cleanup of the Arsenal.

The summary schedule for the program is shown in figure 2. Phase I was actually conducted in two parts. The first part dealt with methods verification for cleanup of heavy metal residues and decontamination of radiological contaminants. The second portion of phase I addressed cleanup of explosives residues in the contract-identified facilities at the Arsenal. As such, phase II was also divided into two portions, namely generation of standing operating procedures describing the detailed operations for cleanup of heavy metals and radiological decontamination with the second portion addressing the detailed procedures for cleanup of explosives residues. Phase III began in late February 1980, shortly after publication of a public notice

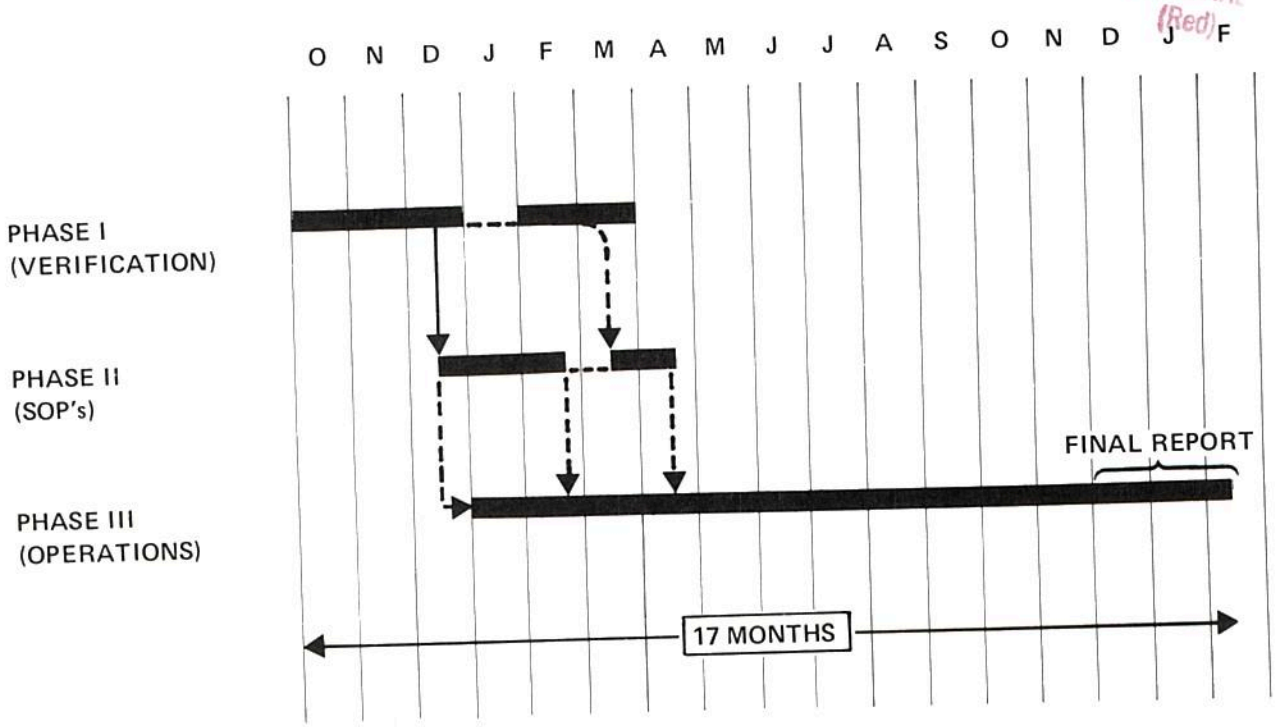

Figure 2. Summary Schedule

announcing the Finding of No Significant Impact and Availability of the Environmental Assessment (figure 3). The actual field decontamination cleanup work was completed just prior to Thanksgiving 1980, with all documentation being finished by mid-January 1981.

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Tuesday, Feb. 26, 1980 Philadelphia Inquirer

Legal Notices **Legal Notices**

PROPOSED DECONTAMINATION CLEAN-UP OPERATIONS AT FRANKFORD ARSENAL, PHILADELPHIA, PENNSYLVANIA; FINDING OF NO SIGNIFICANT IMPACT (FONSI)

The US Army Toxic and Hazardous Materials Agency (USATHAMA) has prepared an Environmental Assessment to evaluate the potential environmental impacts of proposed decontamination/ clean-up operations at Frankford Arsenal, Philadelphia, PA. The following is a summary of the environmental assessment:

A. NEED FOR THE PROPOSED ACTION

In 1976 the Department of the Army declared Frankford Arsenal (FFA) excess to its needs and the facility was officially closed in 1977. USATHAMA was tasked to determine the magnitude of any residual toxic or hazardous contamination remaining as a result of the Arsenal's many years of research, development, manufacturing, testing and procurement. A comprehensive survey revealed the existence of low concentrations of explosive manufacturing residues, heavy metals residues and radiological contamination. None of the contamination presents a threat to public health or the environment under existing conditions, but its presence limits potential use of the Arsenal property. USATHAMA was further directed to develop alternative for release of the facility based on the survey findings.

B. ALTERNATIVES CONSIDERED

The following alternatives were considered with regard to environmental and historical impacts, future reuse of the property and cost/benefit:

1. Identify degree of contamination and release the property "as is."
2. Close the Arsenal and retain the property indefinitely.
3. Decontaminate radiologically contaminated areas and retain the property indefinitely.
4. Decontaminate and release the property for restricted/industrial use.
5. Decontaminate and release the property for unrestricted/public use.

The last alternative has been selected and is the proposed action. It provides the potential for maximum reuse of the property without restrictions while insuring that any health or environmental hazards will be reduced to the greatest possible extent.

C. ENVIRONMENTAL IMPACTS OF THE PROPOSED ACTION

The proposed action has been developed with environmental enhancement as a primary concern. In each case where cleanup operations could have some potential for adverse impact, appropriate mitigating measures have been made an integral part of project planning. The Environmental Assessment presents a detailed analysis of potential impacts and mitigation in the areas summarized below:

1. AIR QUALITY - Any fugitive dust containing contaminants will be controlled using plastic sheeting barriers, wetting techniques, and dust suppressants. Incinerators used to decompose explosives residues will be equipped with air pollution devices to insure that there is no degradation of ambient air quality.
2. WATER QUALITY - The quantity of liquid wastes generated will be kept to a minimum through the use of dry processes such as brushing, foaming and vacuuming. Any drainage will be dammed, diverted, collected and sealed in drums for proper disposal. No release to the sewers will be made without prior approval from the Philadelphia Water Department.
3. SOLID AND HAZARDOUS WASTE DISPOSAL - The clean-up operations will produce approximately 3,500 cubic yards of solid waste with an estimated 500 cubic yards being considered hazardous waste. All hazardous waste generated will be containerized and transported to controlled hazardous waste disposal facilities.
4. ENVIRONMENTAL NOISE - Due to the distance between proposed work sites and neighboring properties and the industrial nature of the area surrounding the Arsenal, it is not anticipated that the proposed operations will result in any significant increase in ambient noise levels in the area.
5. HISTORICAL AND ARCHEOLOGICAL - A comprehensive historical/archeological survey of the site to ensure that future use of the buildings and grounds will be compatible with national preservation objectives has been completed. A Memorandum of Agreement between the Department of Army, the Advisory Council, Council on Historic Preservation and the Pennsylvania State Historic Preservation Officer establishes the stipulations under which the proposed action may proceed.

D. FINDING OF NO SIGNIFICANT IMPACT

1. After review of the Environmental Assessment, it is concluded that the decontamination/clean-up operations at Frankford Arsenal will not constitute a major Federal action having a significant adverse impact on the quality of the affected environment, nor is it likely to be controversial with regard to its environmental impacts.
2. Thus, the requirements of the National Environmental Policy Act (NEPA), the Council on Environmental Quality (CEQ) Regulations and Army Regulation 200-1 have been complied with and a Draft Environmental Impact Statement need not be filed with the US Environmental Protection Agency.
3. Copies of the written Environmental Assessment are available for public review at Frankford Arsenal, the Central and Regional branches of the Free Library of Philadelphia and at the US Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, Maryland. Any comments or questions should be directed to the Commander, US Army Toxic and Hazardous Materials Agency, ATTN: DRXTH-ES, Aberdeen Proving Ground, MD 21010, Telephone (301) 671-3921.

80-F27-22-1

Figure 3. Filing of Public Notice Clears the Way for Starting Phase III

3. PROGRAM OVERVIEW

The Frankford Arsenal Decontamination and Cleanup Program was under the direction of USATHAMA headquartered at the Edgewood area of the Aberdeen Proving Ground in Maryland. USATHAMA is an agency of the Army Armament Material Development and Readiness Command (DARCOM).

The decontamination and cleanup of Frankford was accomplished under Army contract DAAK11-79-C-0135. The $6.3 million cost plus fixed fee (CPFF) contract, awarded on September 21, 1979, was completed on schedule* at a cost of $8 million. The $1.8 million contract cost growth was the direct result of the unexpectedly large extent**of low-level radiological contamination encountered at Frankford during the decontamination effort. Rockwell, as a result of its experience in the field of radiological decontamination, had recognized the possibility of encountering just this type of situation; and in submitting its original proposal in July 1979, Rockwell recommended to the Army "...that a 25% management reserve be established..." to cover the possibility of unforeseen workscope expansion.

3.1 CONTRACT WORKSCOPE

The contract scope of work for Frankford Arsenal Decontamination and Cleanup Program was based upon the results of a presurvey of the facility performed by Battelle Columbus Laboratories (BCL) during the spring and summer of 1978. The BCL survey indicated the presence of three generic types of contaminants, specifically (1) heavy metal residues, (2) minute quantities of explosives residues, and (3) low-level radiological (rad) contamination. The contamination was restricted to certain facilities located in sectors B, C and D of the Arsenal (see figure 1). As noted in section 2, sector A (primarily the living quarters for military personnel

*The final report was submitted 1-1/2 months ahead of schedule.
**The extent of radiological contamination was far greater than that identified by the BCL survey for reasons explained in section 3.5.

assigned to the Arsenal) was certified as clean by the Department of the Army based on previous historical searches and on-site surveys.

The heavy metal residues (lead, cadmium, chromium, and mercury) were due primarily to the lead-based paint used in years gone by on the interior surfaces of many of the Arsenal buildings and to the operation of certain plating and metallurgical laboratories at the facility. The explosives residues, identifiable only in minute quantities (of the order of micrograms per square meter of surface area), were the result of the historical use of Frankford Arsenal as the small-caliber munitions manufacturing and supply center for the United States and as the nation's center of development for cartridge and propellent (CAD/PAD) devices. The low-level rad contamination was due to the use of depleted uranium employed in the development of armor-piercing projectiles along with the use of other special nuclear materials (e.g., radium) for fire control instruments.

When viewed in the light of its long and varied history, the Arsenal was, in fact, remarkably clean. Nevertheless, in order to meet the goal of releasing the facility for unrestricted use, decontamination and cleanup of the Arsenal was required. The contract work scope for this effort is summarized in table 1, and as previously noted the program was conducted in three distinct, chronologically overlapping phases (figure 2).

For purposes of monitoring and controlling the program, the key work elements were defined in a work breakdown structure (WBS) (figure 4). All cost and schedule plans were made directly relatable to these WBS elements, and monthly cost and performance reporting to the customer was in accordance with the WBS. In addition, a cross matrix relating functional departments to the WBS element, identifying cost collection accounts and cost account managers, was developed and implemented to provide cost control and data at the level immediately below the reporting level.

TABLE 1. Contract Workscope

Facility	Contaminants						
	HM	HM/rad	HM/rad/expl	HM/expl	rad/expl	rad	expl
Buildings	113 (116)*	8 (11)*	4 (1)*	10 (7)*	0	0	0
Sumps	0	21	2	0	4	15	0
Vents	26	3	1	2	0	0	0
Sewers	0	0	0	0	0	15**	0
Outside Areas	0	0	0	0	0	4	0
400 Area	DEMOLISH						
329 Platform	REMOVE						

*Redefinition of explosives residues contaminated buildings based on Rockwell assessment (see document N505TI000035), subsequently approved by USATHAMA, resulted in the numbers shown in parentheses.

**Contract required removal of the building 316. The total of 15 includes this sewer.

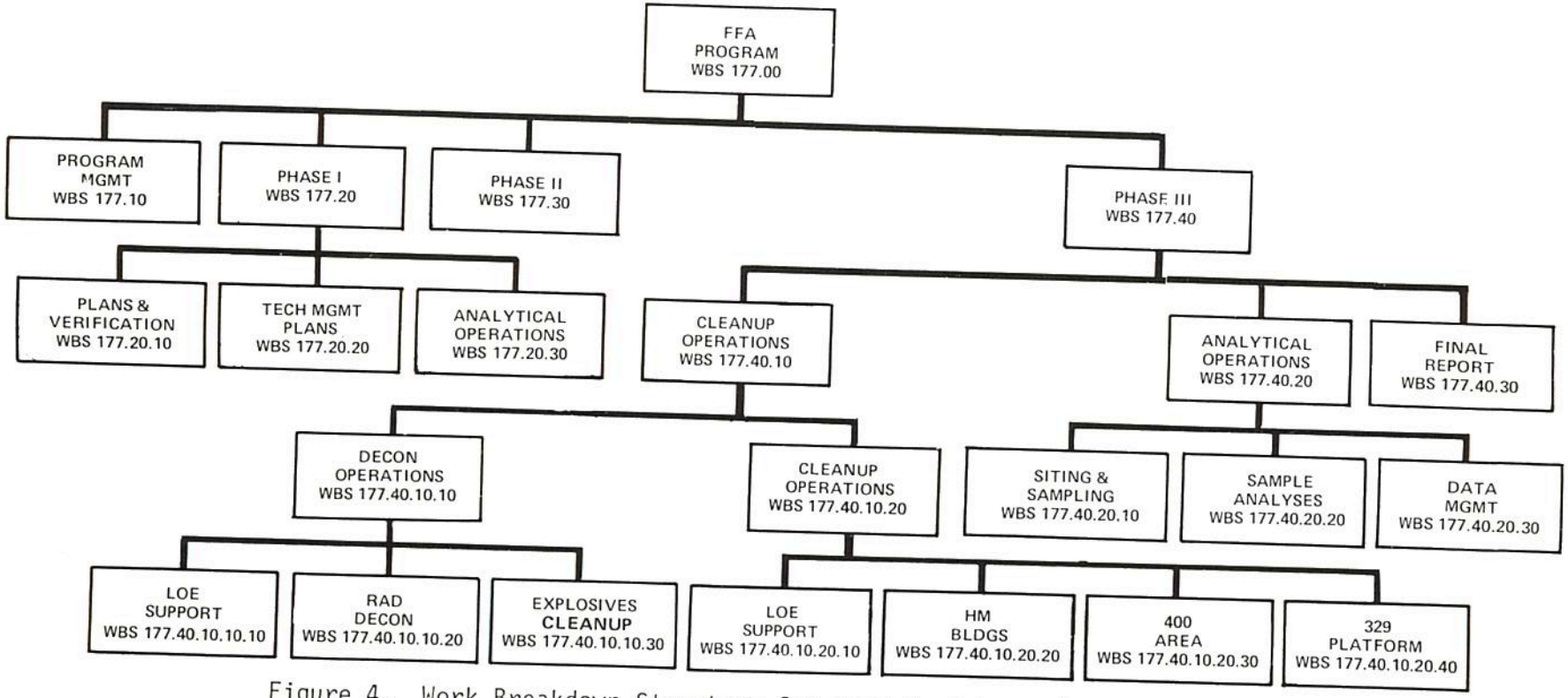

Figure 4. Work Breakdown Structure for Frankford Arsenal Deconamination and Cleanup Program

3.2 TECHNICAL APPROACH

The basic technical approach for the decontamination and cleanup program was reduction of the contamination to acceptable levels following an order of importance associated with maximizing personnel protection. Specifically, the first contaminant to be removed was the explosive residues, the next contaminant to be removed was radiological contamination, with the last contaminant removed being the heavy metals residues. This approach was adopted as noted above to insure personnel safety during the decontamination and cleanup activity.

Where a given facility was identified by the BCL survey as containing all three contaminants, the decontamination activities proceeded in the order noted above. Where only radiological and heavy metals contamination existed, radiological decontamination was accomplished first, followed by cleanup of the heavy metals residue. Where only heavy metals residues were identified, cleanup of these residues proceeded directly.

3.3 PHASE I

Phase I of the program, starting with the contract award on September 21, 1979, was conducted in two parts. The first part, culminating in the initial release of the Interim Technical Report (Rockwell document N505TI000018) on December 20, 1979, validated the proposed cleanup methods for heavy metal residues and rad decontamination. The second part validated the cleanup methods to be employed for explosives residues and was completed with issuance of Revision B of the Interim Technical Report on April 24, 1980.

Specific Arsenal locations representative of conditions in contaminated areas were selected for demonstration and validation of the cleanup methods proposed for use in phase III. For cleanup of heavy metal residues, an isolatable portion of building 116 was selected. For demonstrating rad decon methods, range C of building 316 (for building interiors), building 227B (for outside areas), and the sump on the westerly side of building 120 were selected.

The loading room of building 521 and the sump on the easterly side of building 244A were selected for validating explosives residues cleanup methods for building interiors and sumps, respectively.

The phase I methods, documented in 10 so-called "mini" work plans (which were marked up to reflect phase I findings and subsequently used as the basis for the phase II SOP's), were validated under actual field conditions. Very briefly, the methods validation results from phase I indicated the following:

- Airborne concentrations of heavy metals were within contract acceptance levels, and cleanup of heavy metals residues could be accomplished by the removal of loose and flaking paint, preparation of the surface for painting, and subsequent painting using paint with low lead content (less than 0.06 weight percent).

- Rad contamination was found primarily to be of the fixed variety, requiring physical removal of the surface material. Foaming (a detergent scrub process) was relatively ineffective for the fixed type of contamination encountered.

- Destruction of minute quantities of explosives on building surfaces is readily accomplished by passing a torch flame over the surface at a rate of approximately 10 feet per minute. Explosives residues in cracks require dwelling of the flame over the area for approximately 1 minute. Sumps contaminated by trace amounts of explosives residues can be decontaminated by burning the interior of the sumps using a lighted bed of charcoal briquets, intensifying the combustion by air forced through an aerator pipe installed in the sump.

Details regarding the phase I methods validation results are presented in the Interim Technical Report (Rockwell document N505TI000018). Concurrent with the field validation of the cleanup methods, a number of key documents (see the appendix) were prepared during phase I. Among these were the following USATHAMA-approved Rockwell documents:

- Data Management Plan, N505TI000016
- Cleanness Criteria for Release of Frankford Arsenal for Unrestricted Use, N505SRR000002
- Safety Program Plan, N505SRR000001
- Waste Management Plan, N505TI000027
- Training Plan, N505SRR000003
- Quality Assurance Plan (Data Validation), N505TI000022

These documents formed the agreed-upon basis (in conjunction with the phase II SOP's) for proceeding with the remainder of the work under the contract.

3.4 PHASE II

A total of 15 detailed SOP's were prepared during phase II of the program, which extended from late November 1979 through late April 1980. Two of these, specifically one for the 400 area cleanup and demolition, and the other for removal of the 329 platform, formed the basis, in part, for construction specifications required to subcontract those two elements of work.

3.5 PHASE III

The phase III work began in late February after approval of the appropriate SOP's by USATHAMA and after posting by USATHAMA of the required public notice. The contract workscope for the phase III cleanup effort is shown in table 1. Control of the phase III operations was accomplished through the standing operating procedures generated during phase II of the program.

The first phase III activity started was radiological decontamination of buildings. Shortly after starting the rad decontamination, it became apparent that the extent of radiological contamination at the Arsenal in the contract-identified buildings was greater than that which could be inferred from the results of the BCL survey. This was due to the fact that the buildings were to be decontaminated to a level required for releasing the facility for

unrestricted use, i.e., to very low levels. In many cases, these levels were at or near the background levels associated with the materials of construction used in the Frankford Arsenal buildings (the brick and granite from which the buildings were built). In addition, since the Arsenal had not been used since 1977, dirt and dust had collected on the building surfaces and, due to the extremely low levels to which rad decontamination had to be accomplished, the very presence of this dirt and dust layer served to mask the extent of the radiological contamination. Therefore, it is not at all surprising that the BCL survey identified only the primary "hot spots" as far as radiological contamination was concerned. This as-found workscope associated with radiological decontamination was thoroughly documented in Rockwell document N505TI000034.

A measure of the greatly expanded extent of the radiological contamination may be inferred from the fact that the original estimate for radiological waste volume was approximately 7000 ft^3, whereas the final rad waste volume was approximately 41,000 ft^3. The radiological decontamination effort was the first of the phase III activities to begin and the last of the activities to be finished (just prior to Thanksgiving 1980).

Cleanup of explosive residues began in the early summer of 1980 following approval of the standing operating procedure for flaming of the buildings, sumps, and vents identified in the contract as containing explosive residues. The flaming of the buildings was accomplished both by using automatic remote flamers designed specifically for this task and through the use of hand flamers used in areas inaccessible to the automatic flamers (see figures 5 through 7). The automatic remote flamers were used, again, as a personnel safety precaution to protect cleanup personnel to the maximum extent possible should there be an inadvertent detonation of some hidden explosive residues. Fortunately, no such incidents occurred throughout the entire explosives residues cleanup activity.*

*Detonations did occur during the "400 area burn," which was flamed using the solid fuel (charcoal briquet) approach used for sumps. That approach was used, again, to maximize protection of personnel during cleanup of the 400 area.

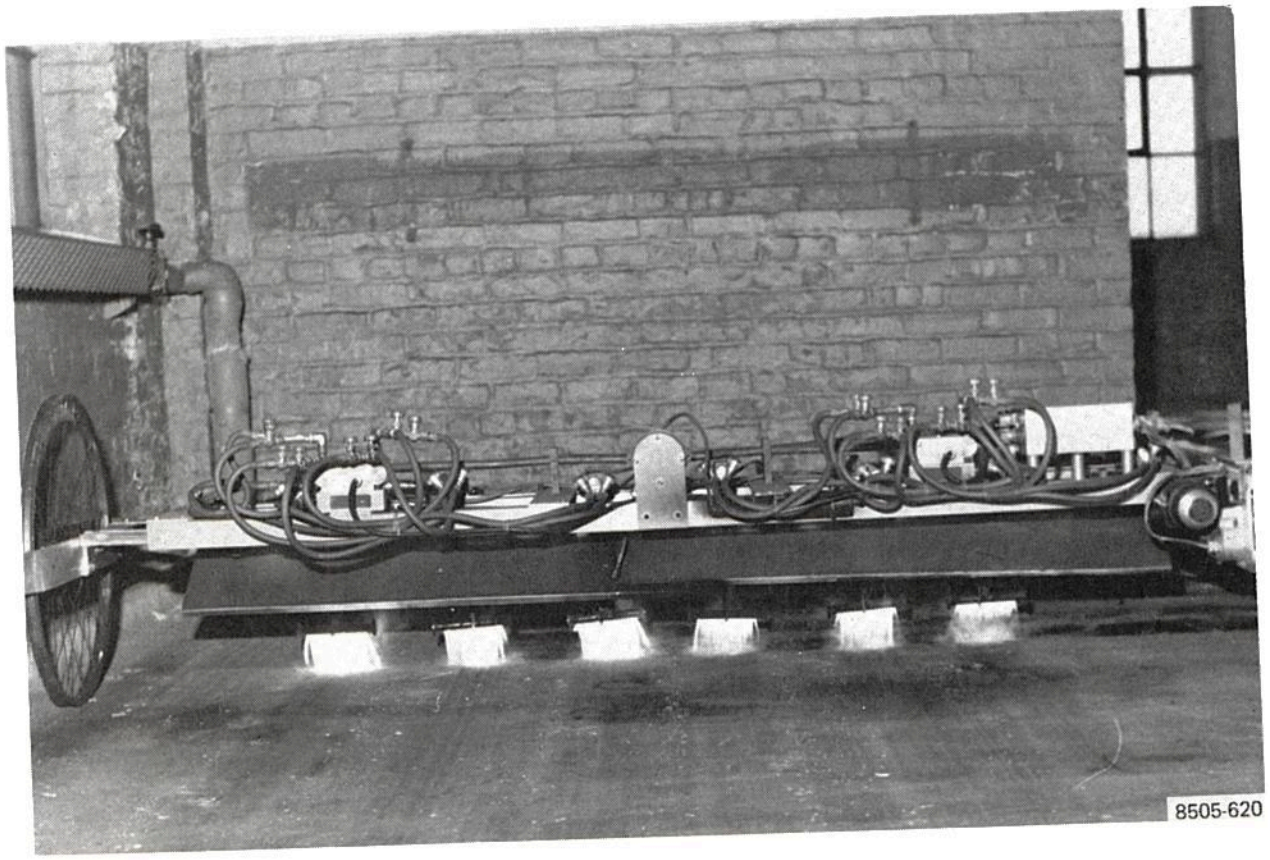

Figure 5. Floor Flamer in Action (torches automatically offset one torch head width at far end of travel, prior to return pass, to ensure full coverage of surface)

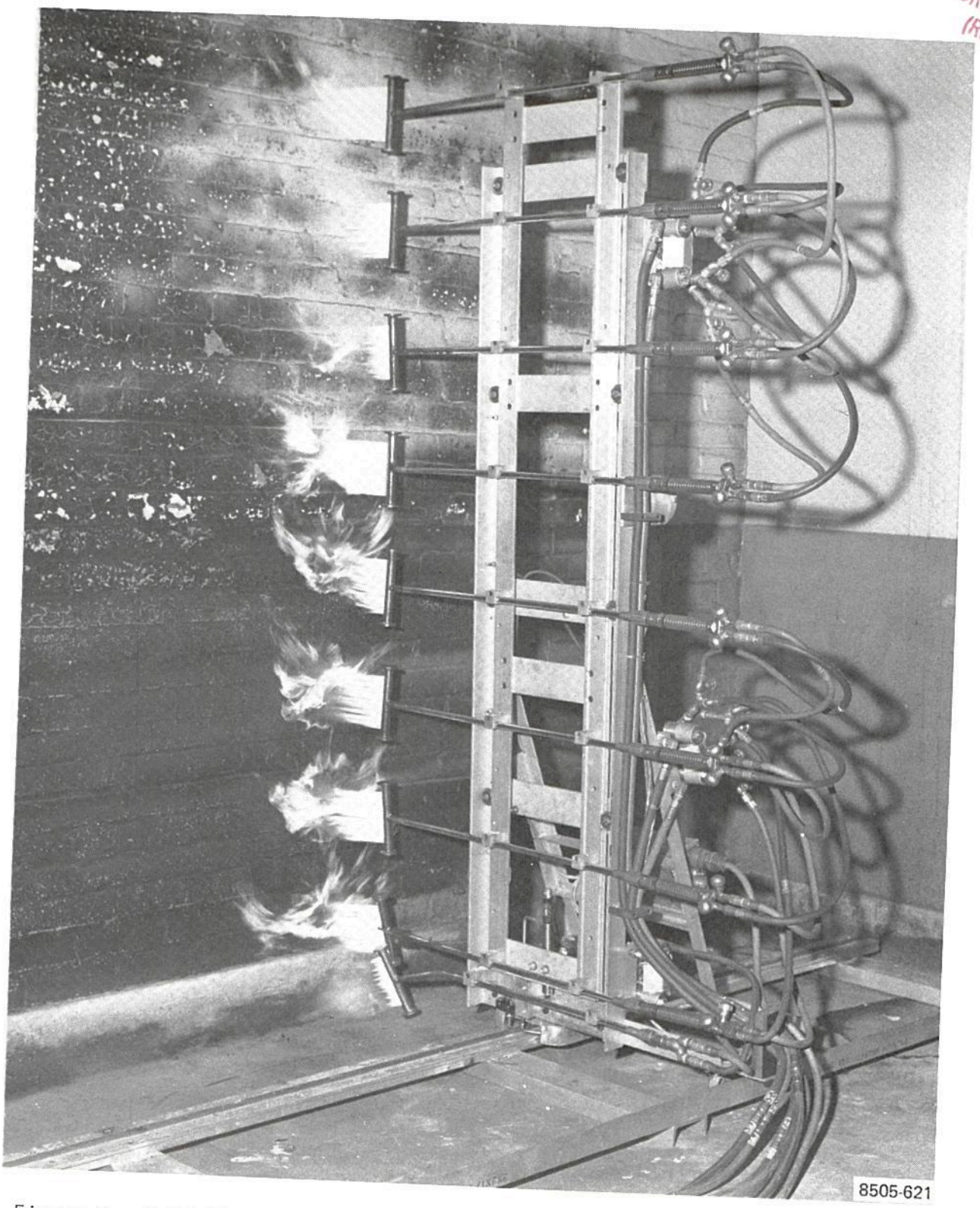

Figure 6. Wall Flamer in Action (torches automatically offset at end of travel – same as floor flamer, see figure 5)

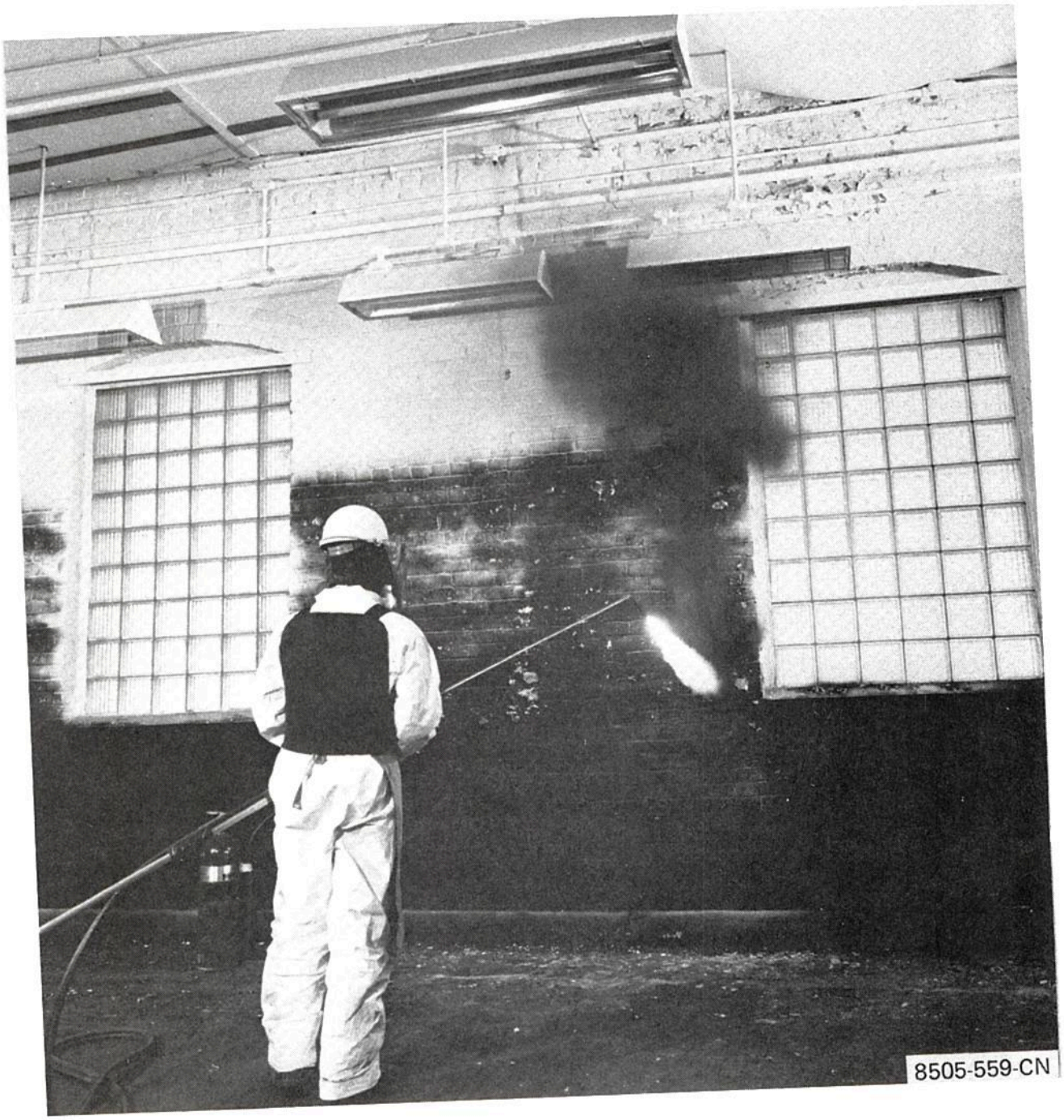

Figure 7. Hand Flaming in Progress

The heavy metal residues identified by the BCL survey consisted of lead, cadmium, chromium, and mercury due primarily to the use of lead-based paint on the building surfaces, which had been used during the past history of the Arsenal. Painted surfaces containing heavy metals that are intact do not pose a health hazard, since the heavy metals in the paint are not bioavailable. Only when the paint is peeling or flaking does it pose a health hazard to children, since it becomes bioavailable. Therefore, cleanup of the heavy metals residue was accomplished in a very straightforward way by removing the loose and flaking paint from the building surfaces, air sampling to assure that the heavy metals concentration was below the acceptance criteria, and then repainting these surfaces (up to a height of 6 feet, which was based on an assessment of bioavailability of the paint layers to children in the buildings) with a low-lead-content (0.06%) paint. The removal of the loose and flaking paint and repainting of the building surfaces were accomplished through a subcontract issued by Rockwell for this element of work.

The contract also called for removal of the 329 platform and demolition of the 400 area. The 329 platform, removed in mid-August, was required to recover and dispose of cannonballs suspected to be lodged beneath the platform. Only seven cannonballs, all inert, were recovered.

The 400 area, a 9-acre parcel located in the southeast part of the Arsenal, was used from World War II onward for manufacture of primer mixes and pyrotechnics. The low value of the 32 small buildings located in the 400 area, coupled with the possibility of contamination with primer mixes and/or pyrotechnic materials, led to the contract requirement for cleanup and complete demolition of the 400 area.

Cleanup was accomplished by the so-called 400 area burn (figure 8) on October 11. The demolition work, subcontracted to a local Philadelphia firm, began 1 week later and was completed by early November.

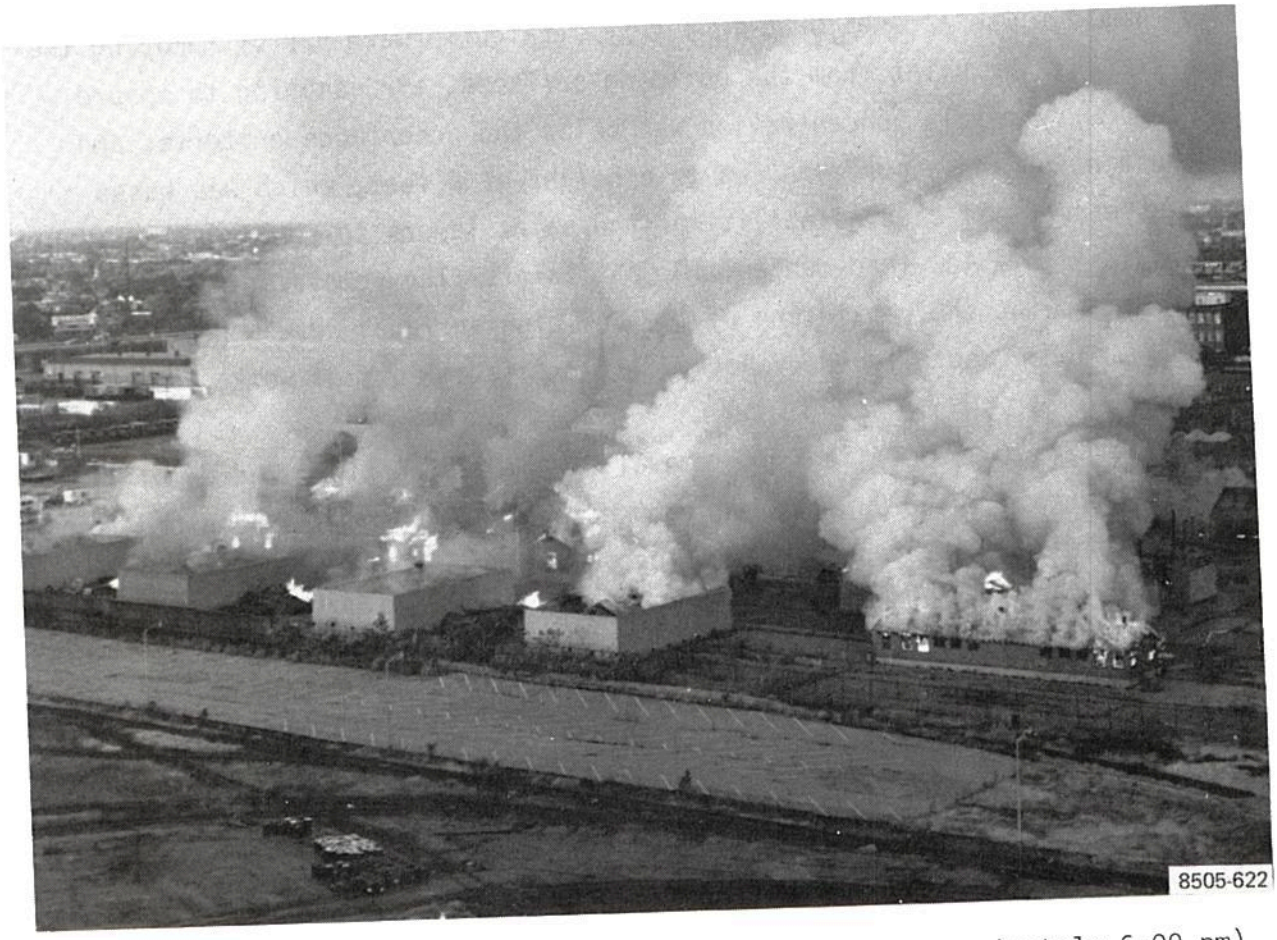

Figure 8. The 400 Area Burn (ignition occurred at approximately 6:00 pm)

4. RADIOLOGICAL DECONTAMINATION SUMMARY

4.1 BUILDINGS

A total of 12 buildings were identified in the contract as containing radiological contamination. These buildings were 46, 64, 108, 121, 149, 150, 201, 210, 227B, 316, 518, and 521. The radiological contaminant was depleted uranium, with the exception of the second floor of building 46, which was contaminated with radium.

As noted in section 3, the extent of contamination in several of the buildings greatly exceeded the amount identified in the presurvey conducted by BCL. This was not true in all cases, however, and in fact, building 201 was found to be free of radiological contamination. At the other end of the spectrum, range C of building 316, the firing ranges 11/12 and 15/16 in building 521, and the second floor of building 046 required extensive decontamination efforts.

Decontamination of the buildings consisted of cleaning the areas in question, removing building surfaces that were contaminated (figure 9), and removing drains (figure 10) and overhead facilities (figure 11) that were identified as radiologically contaminated by the Rockwell surveys conducted during the decontamination process. The radiological waste was then appropriately packaged (figure 12) and shipped for off-site burial to Barnwell, South Carolina for all rad waste except that from building 46 (radium waste), which was sent to Beatty, Nevada.

The decontamination of the buildings was conducted in accordance with Army-approved standing operating procedures listed below:

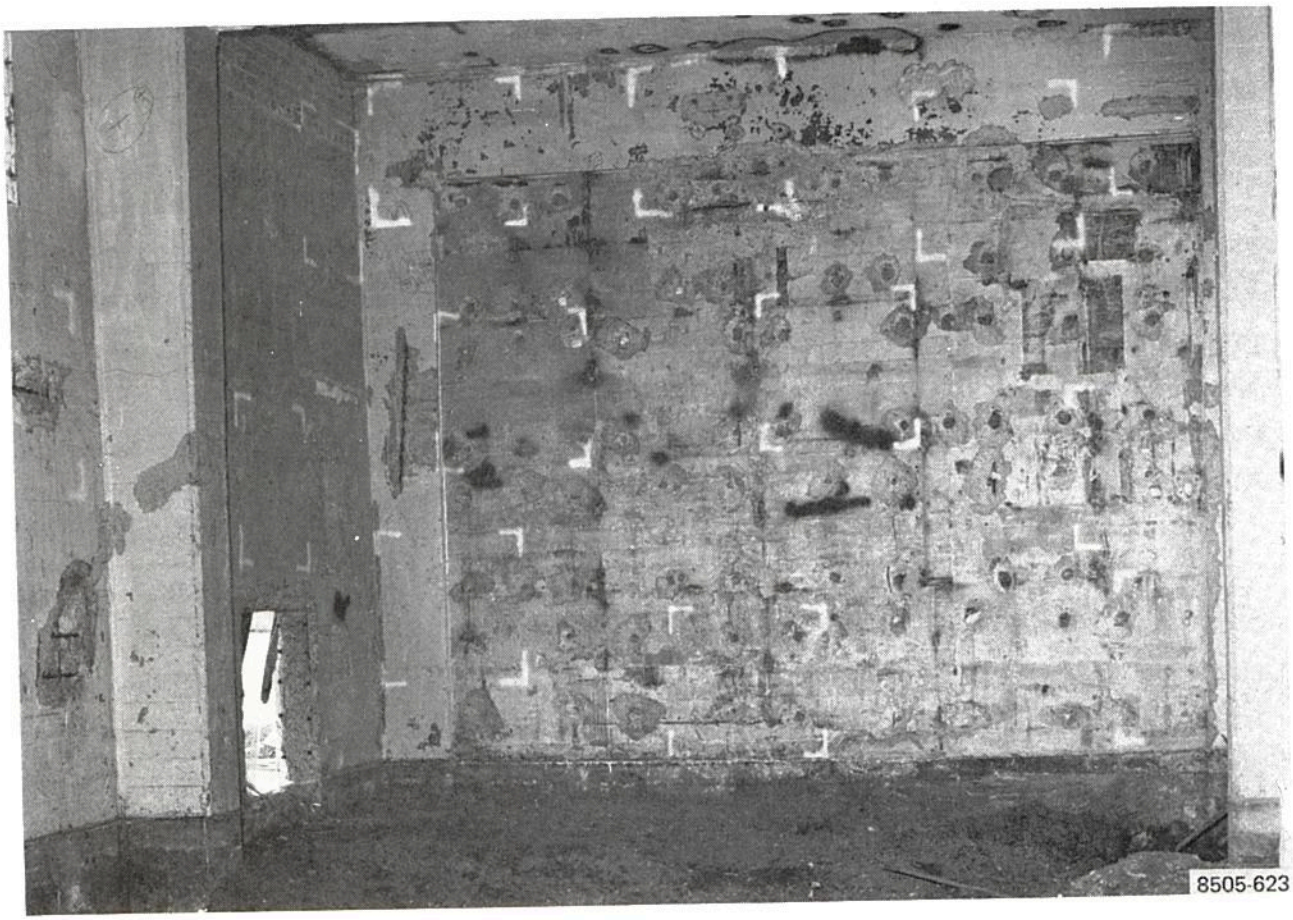

Figure 9. Typical Removal of Rad-Contaminated Building Surfaces (Range C, Building 316)

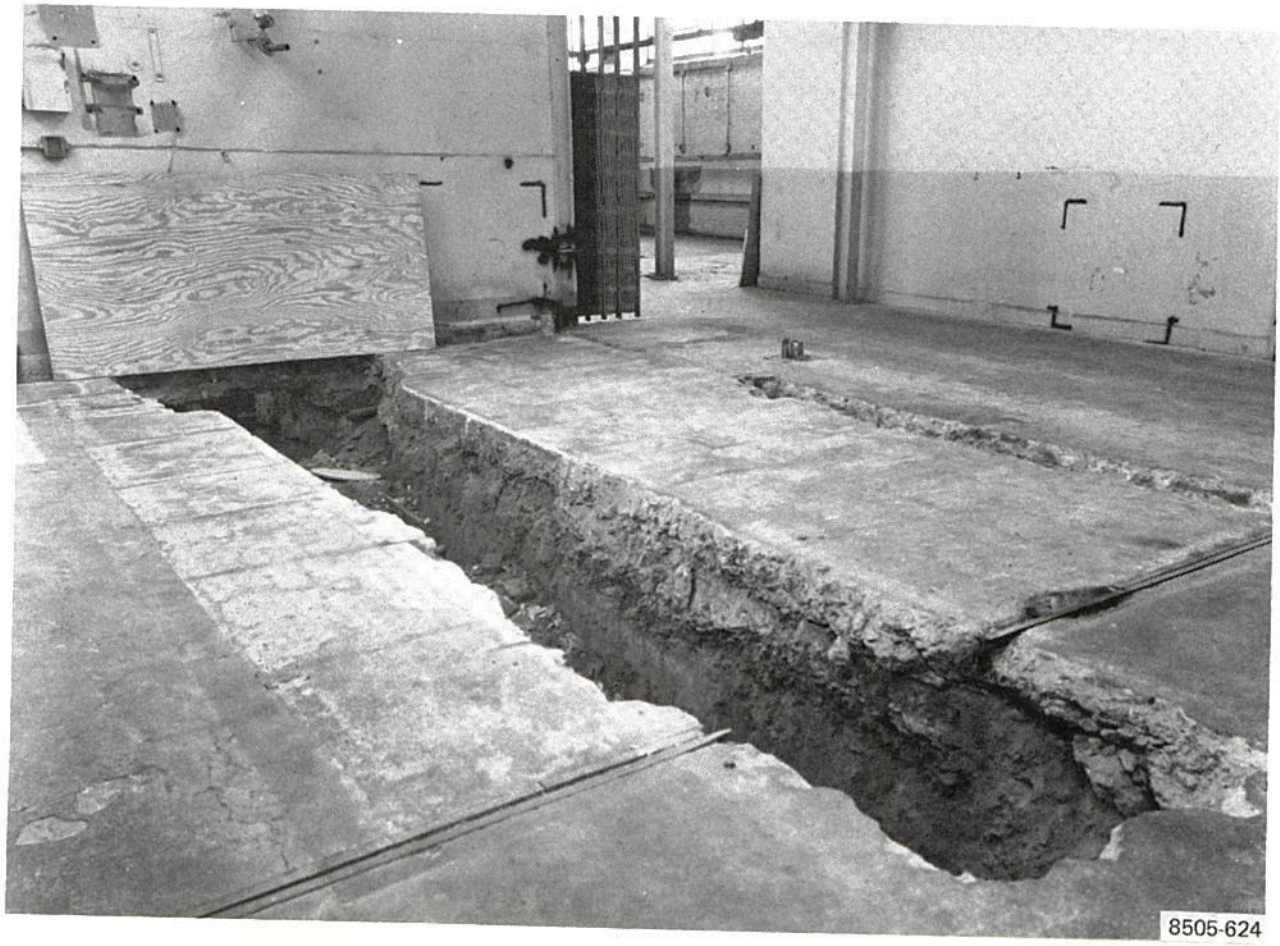

Figure 10. Typical Removal of Rad-Contaminated Drain (Building 149)

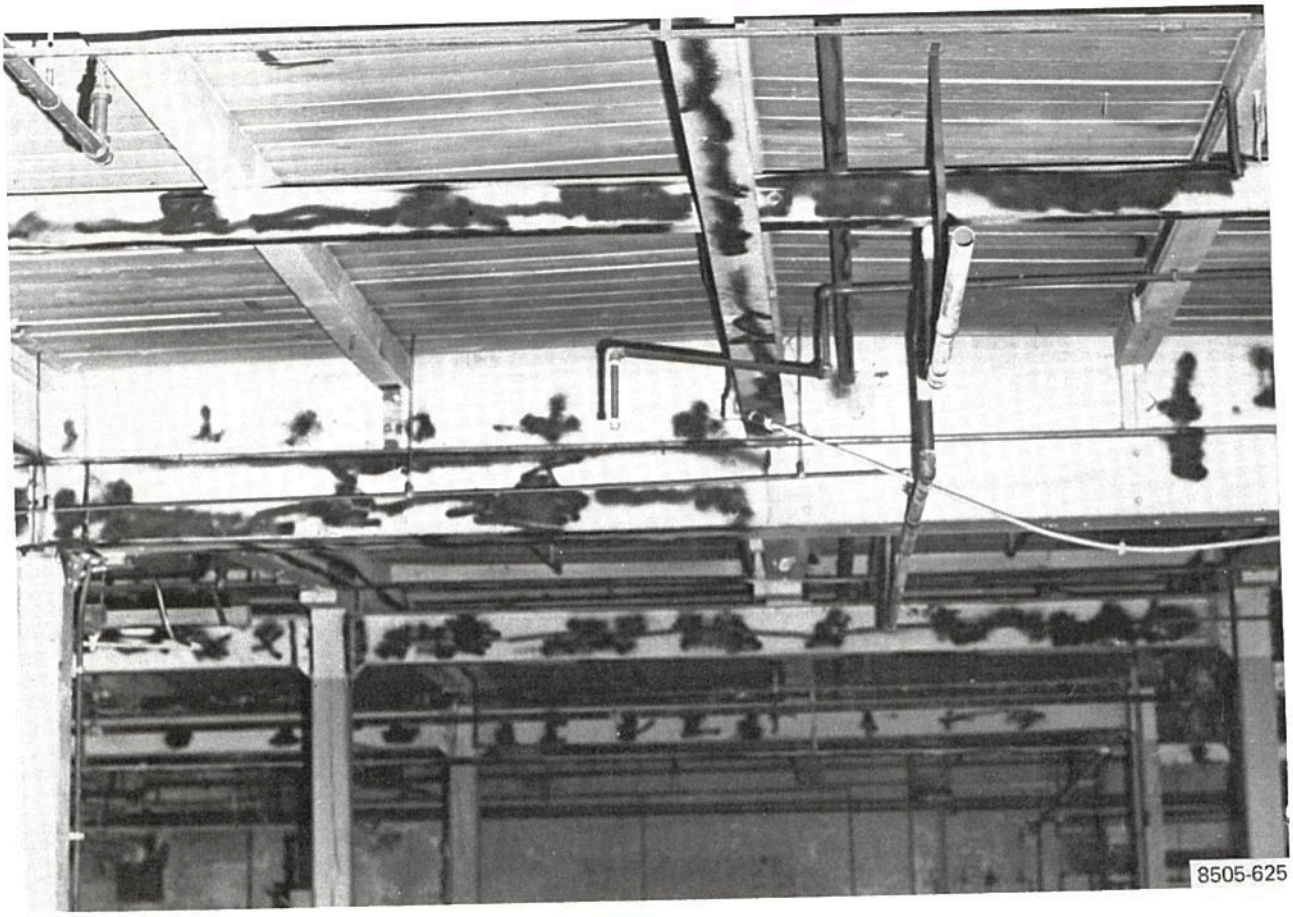

Figure 11. Rad-Contaminated Overhead Facilities (lighting, ducting, piping) Removed in Building 518

Figure 12. Rad Waste Staged (Building 308) for Shipment to Burial Site

Building	Applicable SOP
46	N5050P000015
64, 108, 121, 149, 150, 201*, 210, 227B, 316, 518	N5050P000002
521	N5050P000009

Following decontamination of the buildings, a final radiological acceptance survey was conducted on each building, and the results were documented in a report for that building. Section 9.4.1 lists those reports. These reports were submitted to USATHAMA who then arranged for NRC inspectors to visit the site and verify the findings. NRC toured each building, taking radiological smears and direct instrument readings. NRC subsequently notified USATHAMA of their verification of the Rockwell findings that the buildings met the cleanness criteria relative to radiological decontamination (see section 9.3).

4.2 OUTSIDE AREAS

A total of four outside areas were identified in the contract as being radiologically contaminated. These areas were outside buildings 120/121, 227B, 149/150, and building 316. An overview survey conducted by the Army's BRL RADCON team (Aberdeen Proving Ground) indicated that the apparent rad contamination of the area between buildings 120 and 121 was, in fact, nothing more than a high background reading due to the brick paving used between those buildings. Subsequently, this area was deleted from the contract work scope.

*No rad decontamination was required in building 201.

In the meantime, however, a small outside area adjacent to ranges 15/16 in building 521 was found to be contaminated. This area was decontaminated along with the remaining three contract-identified outside areas.

Decontamination of the outside areas consisted of removal of the contaminated material (figure 13), appropriate packaging of the material, and subsequent shipment of the rad waste to the Barnwell, South Carolina burial site.

Final radiological acceptance surveys were conducted on the outside areas in a manner similar to that conducted in the buildings.

The acceptance criterion for cleanness of the soil was developed during the course of the Frankford Arsenal program. The acceptance criterion was developed on the basis of a special soil sampling and analysis program conducted by Rockwell under authorization from USATHAMA. The cleanness

Figure 13. Removal of Rad-Contaminated Soil Outside of Building 316

criterion for soil (see section 9.3 of this report), approved by the NRC as a guideline specifically for the Frankford decontamination program, was 35 pCi/gm above natural background in soil in the general Frankford vicinity. Using this acceptance criterion, samples were taken, and analyzed, and the results were documented in a specific report dealing with the outside areas (see document N505SRR000020). Subsequently, NRC toured the area, verified the findings, and notified USATHAMA as to the acceptance of the radiological decontamination of the contract-identified outside areas.

4.3 SUMPS

A total of 42 buildings (excluding the 400 area) were identified as having associated sumps with radiological contamination. Rockwell's surveys of these sumps indicated that, in fact, the sumps were clean* with respect to radiological contamination and no decontamination work was required. The results of the Rockwell surveys of these sumps were presented in an appropriate report issued to USATHAMA (see document N505SRR000022). NRC acceptance of the sumps was based on their verification of these Rockwell findings.

4.4 SEWERS

The contract identified sewers associated with 15 buildings as containing radiological contamination. Radiological surveys by Rockwell indicated, in a manner similar to the sumps, that sewers were not radiologically contaminated (i.e., the sewers satisfied the acceptance criteria for such facilities listed in the cleanness criteria). A report was prepared to this effect, sent to USATHAMA, and formed the basis for subsequent NRC acceptance of the sewers.

*The 400 area sumps were also found to be clean with respect to rad contamination.

4.5 VENTS

Four buildings were identified in the contract as containing radiologically contaminated vents. These buildings were 150, 201, 316, and 521. The vents in buildings 150 and 201 had been removed prior to Rockwell's moving onto the Arsenal site. The vent in building 316, after flaming to remove any explosive residues (in accordance with SOP N5050P000005) was removed and disposed of as rad waste at the Barnwell site.

Two contaminated vents were found in building 521, specifically the 20-inch vents serving firing ranges 15 and 16. These vents were encased in concrete and would have presented a significant effort to remove the vents for disposal as rad waste. Therefore the vents were cleaned in place using a sandblasting technique, and the contaminated sand was shipped as rad waste to Barnwell.

In addition, a contaminated vent was found during decontamination work in building 149. This vent was removed in accordance with SOP N5050P000008 and shipped to the Barnwell burial site.

Certification regarding removal of rad-contaminated vents was issued in Rockwell report N505SRR000023 and served as the basis for NRC acceptance of the radiological decontamination of vents at Frankford Arsenal.

5. CLEANUP OF EXPLOSIVE RESIDUES

5.1 BUILDINGS

A total of 14 buildings at Frankford (exclusive of the 400 area) were identified in the contract as containing explosive residues. These buildings were 64, 68, 69, 149, 151, 151A, 201, 214, 214A, 222, 235, 305, 307, and 521. Subsequently, Rockwell assessed the BCL data and (1) based on the quoted detection limits for the BCL analytical techniques used to identify the buildings as containing explosive residues and (2) further, based on the history of the buildings involved, recommended deletion of six of the buildings from the contract work scope. The buildings, subsequently approved for deletion by USATHAMA, were 64, 149, 201, 235, 305, and 307. Therefore, a total of eight buildings remained in the contract workscope for cleanup of explosive residues.

Based on phase I work, flaming was used to destroy explosive residues on the building surfaces. Special remote flamers were designed and built for this purpose. A floor flamer (see figure 5) and a wall flamer (see figure 6) were built and utilized in the larger buildings (214 and 222). Hand flaming was used as an adjunct to the remote flamers to reach areas inaccessible to the mechanized units (see figure 7). Hand flaming techniques were also used on the smaller buildings. Flaming was conducted in accordance with the following Army-approved standing operating procedures:

Remote flaming (214 and 222) ——→ N5050P000014

Hand flaming (all remaining buildings and detailing of 214/222) ——→ N5050P000018

Acceptance of the buildings was based on thin-layer chromotography techniques (in accordance with EMSC8506.2-1 SOP) to verify that the identified explosive residues contaminants were below detection limit. These results were formalized and certification reports were subsequently issued to USATHAMA (see section 9.5).

5.2 SUMPS

The sumps associated with six buildings (exclusive of the 400 area sumps) were identified in the contract as containing explosive residues. The sumps associated with buildings 58, 68, 122, 213, 219, and 244A required explosives cleanup.

Based on the phase I methods verification, a technique was developed for flaming the sumps consisting of loading the sumps with a bed of charcoal briquets after an aerator line had been installed. The sump charcoal was then soaked with kerosene and ignited using remotely detonated squib devices (see document N505TI000061). Intense heat was developed as the charcoal, fed with compressed air through the aerator pipes, burned (see figure 14). Temperatures in excess of 2500°F were measured during the phase I method verification.

Figure 14. Buring a Sump to Destroy any Explosive Residues

The sumps were burned using the above technique in accordance with the approved SOP N5050P000013. Following flaming of the sumps, a report (N505TI000056) was sent to USATHAMA certifying that the work had been completed.

5.3 VENTS

Vents associated with three buildings were identified in the contract as containing explosive residues. These buildings were 240, 305, and 316. The vents in buildings 240 and 305 had been removed prior to Rockwell's entry onto the site. The vent in building 316, firing range C, which also contained radiological contamination, was flamed in accordance with approved SOP N5050P000005 and subsequently removed in accordance with SOP N5050P000008 for shipment as rad waste to the Barnwell site. Certification as to the decontamination of the contract-identified explosive residues vents was issued in Rockwell report N505SRR000023.

6. CLEANUP OF HEAVY METAL RESIDUES

6.1 BUILDINGS

One hundred and thirty-five buildings (exclusive of the 400 area) were identified in the contract as containing heavy metal residues. These residues consisted of lead, cadmium, chromium, and mercury. The source of the heavy metal residues was, in most cases, the lead-based paint used in past years for painting the interior surfaces of the Arsenal buildings. Mercury contamination in a few of the buildings was found to be the result of spills of laboratory quantities of mercury.

The acceptance criteria for cleanness of the buildings were based on the airborne content of the identified heavy metals (see section 9.3). The contract required that air samples be taken both before and after cleanup of the buildings. The contract also required that the buildings be painted with a paint containing no more than 0.06 weight percent lead in order to restrict the bioavailability of the lead-based paint when the Arsenal is released for unrestricted use.

Based on phase I work, it was found that the airborne heavy metal content in the building was actually below acceptance level and that the only work required would be the removal of loose and flaking paint, preparation of the surfaces for painting, and subsequent painting of the buildings to meet the Surgeon General's bioavailability requirement. In addition, USATHAMA obtained approval through the Surgeon General's office to paint only to a 6-foot height, thereby limiting bioavailability of the lead-based paint relative to people who might occupy the buildings after release of the Arsenal.

The cleanup and painting of the buildings was subcontracted by Rockwell to a small business firm located in Philadelphia. The contract was awarded on May 19, and final painting of the buildings was completed just prior to Thanksgiving 1980. Figure 15 shows typical paint conditions in a heavy metal

Figure 15. Typical Condition of Heavy Metal Contaminated Building Prior to Cleanup

contaminated building before cleanup. Figure 16 shows typical conditions after cleanup and prior to painting. Figure 17 shows typical conditions after the building had been painted.

Certification that the buildings meet the heavy metal residue cleanness criteria (see section 9.3) is contained in Rockwell document N505TI000055.

6.2 SUMPS

Twenty-three buildings were identified in the contract as containing sumps contaminated with heavy metal residues. The liquid layer (water) in the sumps was analyzed and then discharged into the city sanitary sewer system following approval by the City of Philadelphia (see Rockwell document N505TI000064). The remaining sump sludges were then removed from the sumps

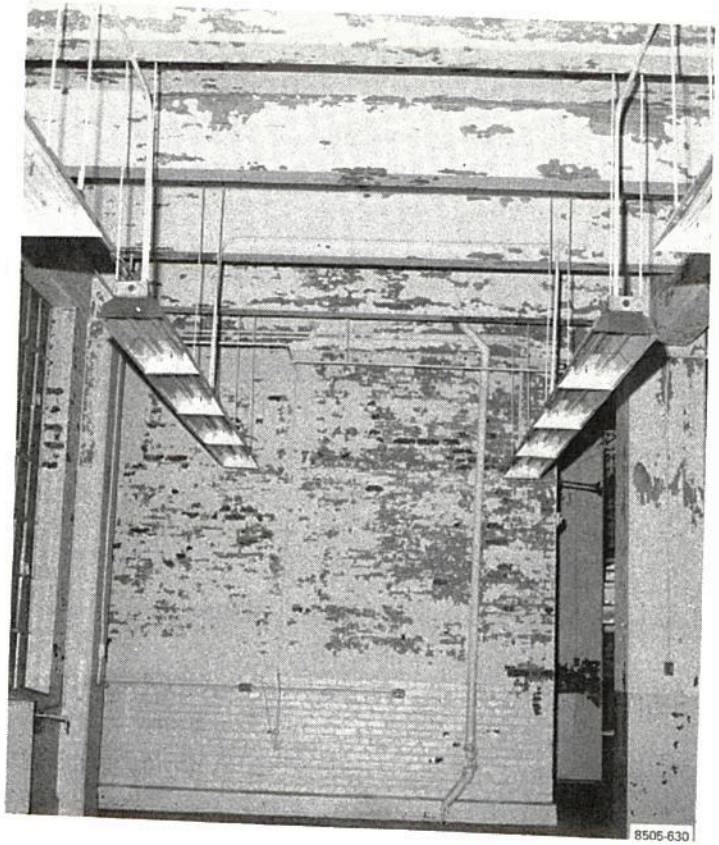

Figure 16. Typical Condition of Building After Cleanup (before painting)

Figure 17. Typical Condition of Building After Painting

and disposed of in an approved landfill (see Rockwell document N505TI000064). The sumps were thoroughly rinsed with high-pressure water and then sampled and analyzed in accordance with Army-approved SOP EMSC8506.2-1. The results indicated that all but nine sumps met the cleanness criteria specified in section 9.3. The nine sumps that exceeded the cleanness criteria (five associated with building 046, three with building 119, and one with building 219) were backfilled with concrete to render them inoperable. Certification of these results may be found in Rockwell document N505TI000062.

6.3 VENTS

The vents in 32 of the buildings at the Arsenal were identified as containing heavy metal residues contaminants. Based on the fact that the buildings were found to meet cleanness criteria before any cleanup operations occurred, Rockwell and USATHAMA agreed to sample the vents in a manner similar to that employed for the buildings. This sampling was conducted, and it was found that the vents met the airborne cleanness criteria for heavy metal residues with no other cleanup action required. Certification of these results may be found in Rockwell document N505TI000063.

7. REMOVAL OF THE 329 PLATFORM

During the original Army assessment of the Arsenal site, several hundred cannonballs were retrieved from the vicinity of the 329 platform. Other cannonballs were seen to be lodged beneath the platform. As a result, the contract required removal of the 329 platform, retrieval of the cannonballs, and certification by the Navy EOD team that proper disposal of the cannonballs had occurred.

The 329 platform (figure 18) was removed and seven cannonballs were retrieved (figure 19). The seven cannonballs were certified as inert by the Naval EOD team, who had arrived on the site to direct the removal and excavation process. Certification of these results are presented in Rockwell report N505TI000047. Following removal of the platform, the platform rubble was placed in the excavation and the area backfilled to grade (see Figure 20).

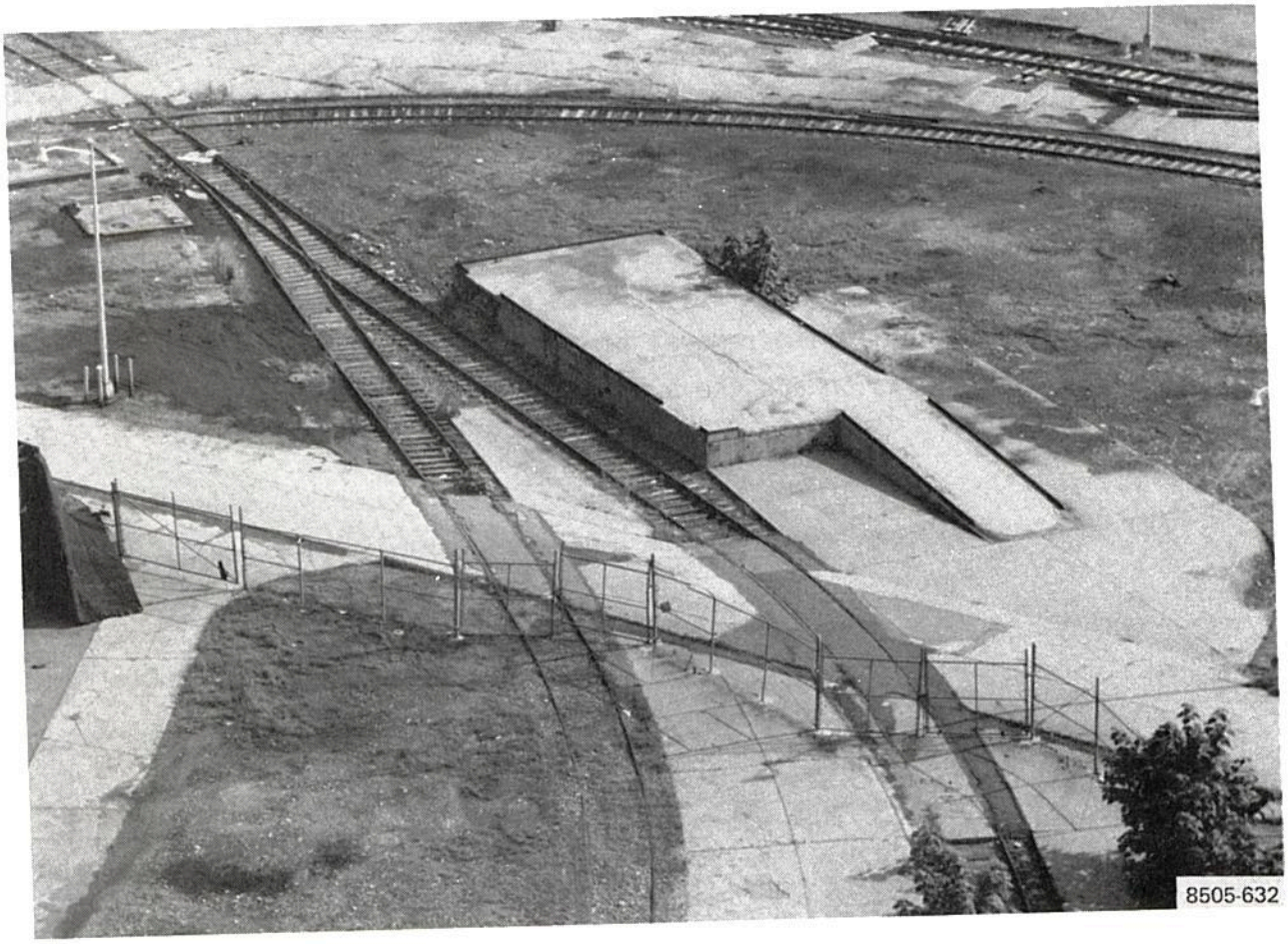

Figure 18. The 329 Platform

Figure 19. Excavating for Cannonballs

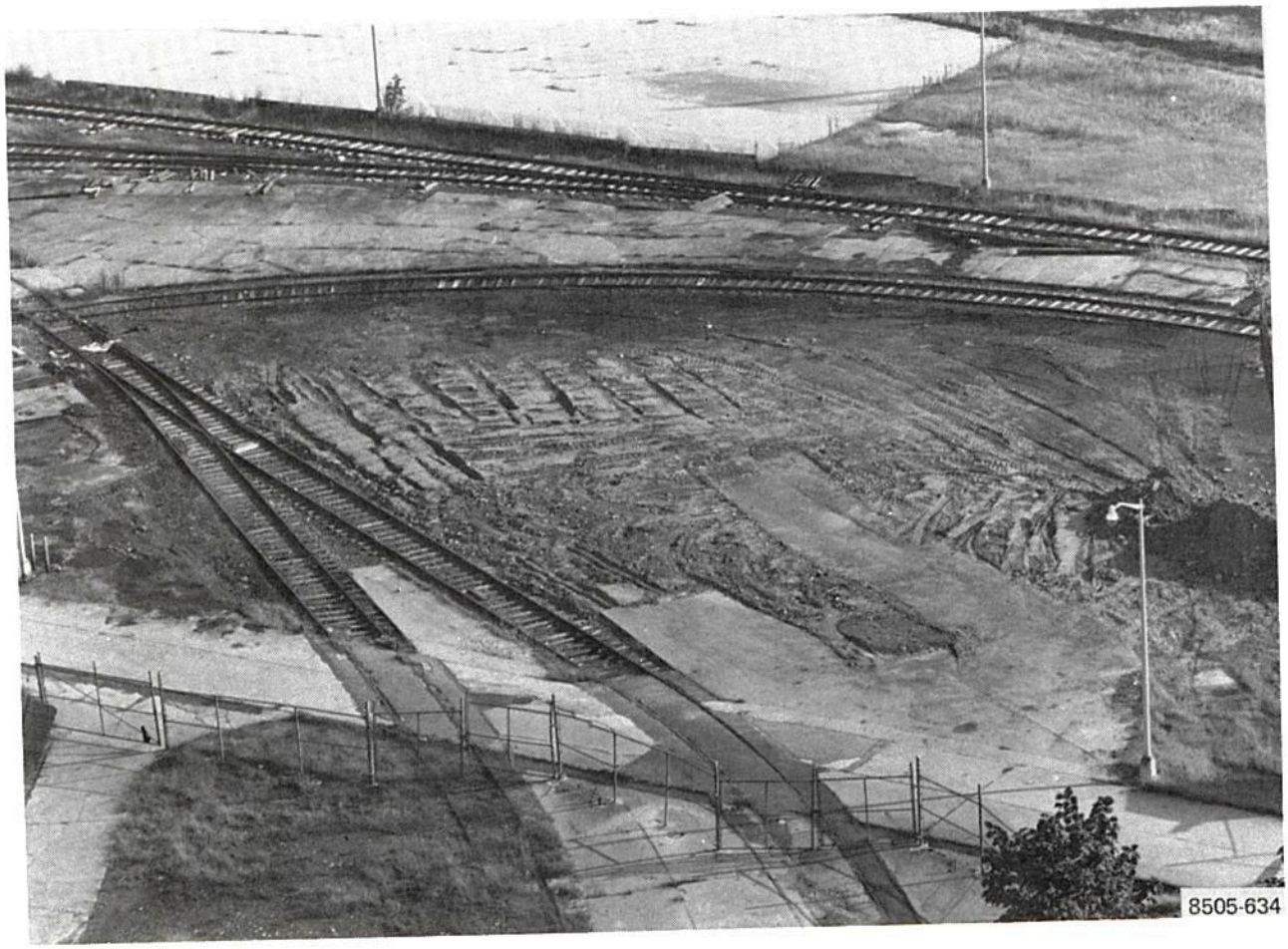

Figure 20. 329 Platform Removed

8. DEMOLITION OF THE 400 AREA

The so-called 400 area at Frankford Arsenal is a 9-acre tract located in the southeast corner of the base. This area, constructed during World War II, was used as a manufacturing area for primer mixes and pyrotechnic material. Thirty-two small buildings, associated sumps, and sewer system existed in the area. Because of the low worth of the buildings and their history as an explosive manufacturing facility, the contract required that the 400 area be cleaned up of any explosive residues remaining and the area demolished and leveled to grade. This required removal of the blast wall footings, the sumps, all subsurface drains, and of course the buildings themselves.

The Army-approved approach (see SOP N5050P000001) used in the cleanup and demolition of the 400 area is shown in figure 21. Very briefly, the approach consisted of stripping the area of friable asbestos and transite ceiling panels (which were properly packaged and disposed of as asbestos waste) and removal of the wooden walkways (which were piled behind the blast walls). The buildings and sumps were then loaded with charcoal in a manner similar to that employed for explosives cleanup of the sumps (section 5.2), the charcoal beds were soaked with kerosene, and the charcoal beds were remotely ignited.

The resulting "400 area burn" (figures 8, 22, and 23) occurred on October 11, 1980, after nearly 3 months of discussions with the City of Philadelphia, culminating in city approval on October 10, 1980 for the burn. Local civic and community action groups and the media had been coordinated through a "test burn," involving two of the small buildings in the 400 area, which had taken place on October 3, 1980 (figure 24).

At least two detonations occurred during the burn. Rockwell observers on the scene reported "feeling the ground shake." The apparent result of one of these detonations was the blowout of the south wall of building 405 (figure 25). These occurrences vindicated the choice to "burn" the entire 400 area as a precaution to maximize personnel safety during the 400 area cleanup.

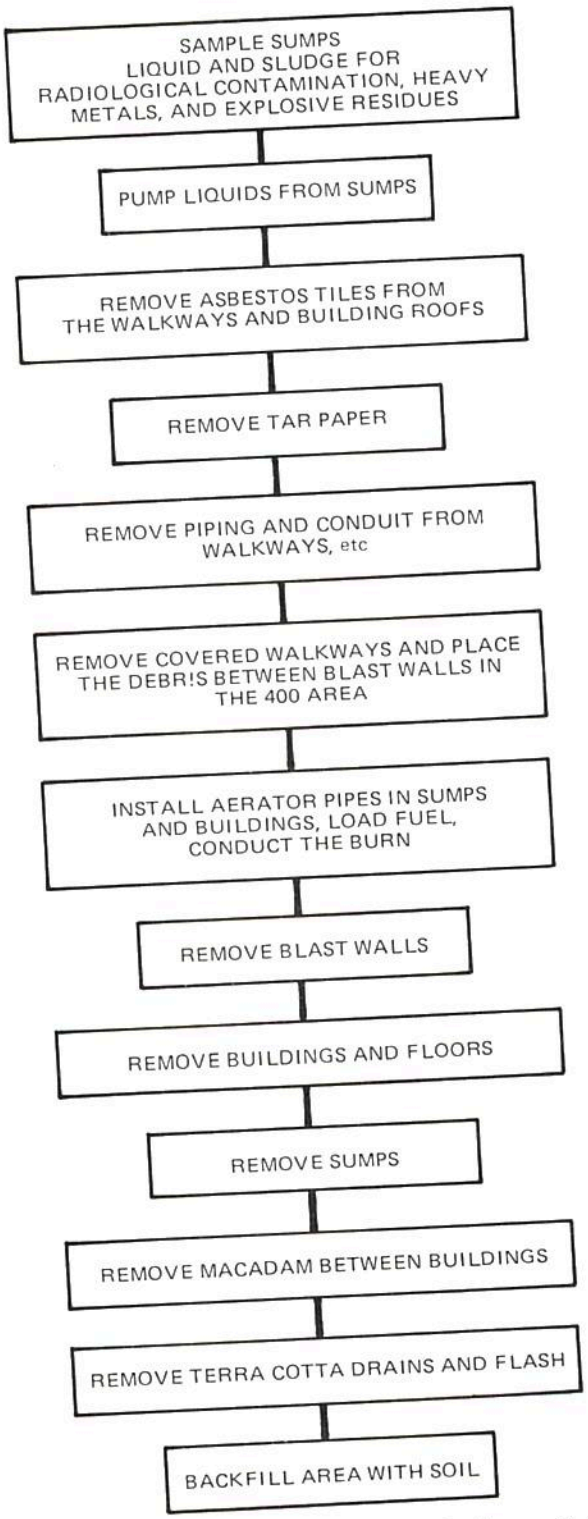

Figure 21. Cleanup and Demolition of 400 Area

Figure 22. 400 Area Burn at Twilight (approximately 7:00 pm)

Figure 23. 400 Area Burn in Final Stages (approximately 8:00 pm)

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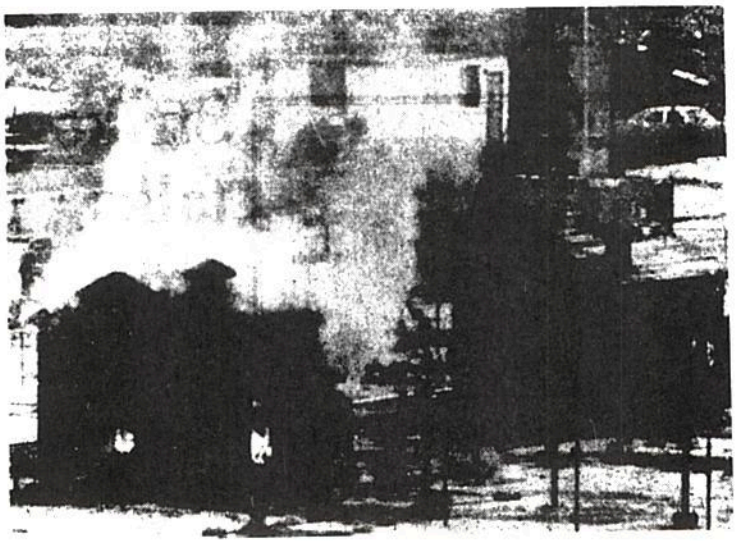
The Philadelphia Inquirer
new jersey & metro

section B

♦ Saturday, October 4, 1980



Philadelphia Inquirer / WILLIAM F. STEINMETZ

Buildings at the Frankford Arsenal undergo a 'test burn' to determine presence of explosives

No blast, and a hardly a fire, so no need to stop the presses

By Edgar Williams
Inquirer Staff Writer

It was about as exciting as a defective barbecue grill. Just about the only thing missing was the relish.

Shortly before 3 p.m. yesterday, in what was termed a "test burn," two small brick structures at the Frankford Arsenal were set afire. Not since the 1975 mayoral campaign has so much smoke been blown about so little in Frankford.

If you're wondering how any structure of brick, the only wood component of which is the roof, can be burned, the trick is to first cover the floor with kerosene-soaked charcoal to a depth of one foot. Then ignite it and let it burn for a couple of hours. Eventually, the roof attains combustion.

And if there is any gunpowder secreted anywhere in the building, it will attain combustion, too.

Which is what the test burn at the arsenal, which was closed in 1977, was all about. Thirty-two buildings in which powder was manufactured and/or stored over the years are scheduled for demolition to make way for a regional marina and park, to be built by the Pennsylvania State Fish Commission.

The U.S. Army, in one of its last official performances at the installation, is making certain that there are no unhappy, explosive surprises when the buildings are burned.

"It is Army policy to burn such buildings before demolishing them, on the long chance that there may be a buildup of explosives that fell through the cracks, so to speak," said Salvatore Torrisi, project engineer who has been assigned to Frankford by the Army Toxic and Hazardous Material Agency, based in Aberdeen, Md. "Should there be any (buildup of explosives), they are burned off, and demolition can be done safely."

For the arsenal job, the Army contracted with Rockwell International Corp. Rockwell surveyed the situation, then began preparing for the simultaneous burning of the 32 structures — some brick "cubicle" buildings, the others concrete-block, bunker-type structures.

Whereupon the city solicitor's office said no.

"We insisted on a test burn," Kenneth Cooper, assistant city solicitor, said yesterday. "There are problems such as air pollution and fire potential that must be examined carefully. Basically, it comes down to protecting the community."

Anthony F. Lillie, site director for Rockwell International, said the company was "more than willing" to cooperate with the city. For the test burn, Lillie invited business people and representatives of civic groups in the Frankford-Bridesburg area to attend as observers. At least one seemed persuaded that the burning process wasn't something to be feared.

"It's just slightly smokier than our backyard barbecue," said Sophie Cochrane, representing a Frankford orgnaization called PAN (Protect A Neighborhood).

Whether the remaining 30 buildings in what is known as the 400 Area at the arsenal (all buildings therein have numbers in the 400s) will have to be burned two at a time or will all be ignited together probably will be determined by the city next week.

Figure 24. Newspaper Account of the 400 Area Burn

Figure 25. South Wall of Building 405 was Blown Out

Figure 26. 400 Area Demolition in Progress

Figure 27. Area Completed

Demolition of the 400 area was subcontracted by Rockwell to a local Philadelphia firm. Demolition began on Friday, October 17, and was completed 17 calendar days later. The footings, sumps, and sewers (which were flamed after removal) were excavated, the buildings demolished (figure 26), and the area leveled to grade (figure 27).

9. CERTIFICATION OF RESULTS

9.1 DATA MANAGEMENT

The Department of the Army's Installation Restoration Data Management System was employed on the Frankford program. All of the data generated relative to the heavy metal residues, radiological contamination, and explosive residues cleanup obtained at the Arsenal during the decontamination and cleanup program are contained in tier 2 of this system.

A data management plan was developed by Rockwell in accordance with contract requirements and approved by the Army for use at Frankford. The data management plan is presented in Rockwell document N505TI000016. Briefly, the data management plan called for identification and siting of the physical locations where samples were taken, permanent marking of that site using a metal tag affixed to the surface being sampled, sampling and analysis in accordance with Army-approved procedures, and entering of the results into the IR data management system. Following quality assurance verification, the data were raised to tier 2 level using an on-site Tektronix computer furnished to Rockwell by USATHAMA for use at the Frankford site.

9.2 QUALITY ASSURANCE

Rockwell Quality Assurance was applied to the gathering of data, verification that procedures were followed during decontamination activities, verification as to the correctness of the data results, and final certification of the results obtained. The facilities certification summary (document N505TI000055) contains the Rockwell Quality Assurance verification that the work has been completed to contract requirements. This document is intended to form the primary basis for subsequent release of the Arsenal to GSA by the Army.

9.3 CLEANNESS CRITERIA

It was recognized early in the program that cleanness criteria for the contract-identified contaminants had to be assembled and approved by the customer in order to define a firm basis for declaring the Arsenal releasable for unrestricted use. Most of the criteria existed (either as specified in the contract or in existing ANSI/NRC standards). Soil cleanness criteria for depleted uranium did not exist and these criteria had to be (and were) developed during the program.

Because of the importance of these criteria to the Frankford Arsenal decontamination and cleanup and because of the precedent these criteria may establish for other programs of this type, the criteria (presented in Rockwell document N505SRR000002) are presented in full.

9.3.1 Surface Contaminants

9.3.1.1 Heavy Metals

Acceptable cleanness of surfaces, relative to heavy metals, is to be established by measurement of airborne concentrations and determination that the airborne concentrations are below the contract-specified levels. Maximum concentrations of heavy metals in air per the Surgeon General are as follows:

Mercury	1.6 $\mu g/m^3$
Cadmium	1.6 $\mu g/m^3$
Chromium	1.6 $\mu g/m^3$
Lead	1.5 $\mu g/m^3$

9.3.1.2 Explosives

Acceptable cleanness of surfaces, relative to explosives, is established by flashing or flaming in accordance with the contract and then sampling using TLC to assure that explosives concentrations are below detectable levels.

9.3.1.3 Radioactive Material

Acceptable cleanness of surfaces, relative to radioactive material, is established by demonstrated conformance to the limits for total and removable activity as follows:

Nuclides[a]	Average[b,c,f]	Maximum[b,d,f]	Removable[b,e,f]
U-nat, U-235, U-238, and associated decay products	5,000 dpm α/100 cm^2	15,000 dpm α/100 cm^2	1,000 dpm α/100 cm^2
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100 dpm/100 cm^2	300 dpm/100 cm^2	20 dpm/100 cm^2
Th-Nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000 dpm/100 cm^2	3,000 dpm/100 cm^2	200 dpm/100 cm^2
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000 dpm $\beta\gamma$/100 cm^2	15,000 dpm $\beta\gamma$/100 cm^2	1,000 dpm $\beta\gamma$/100 cm^2

a Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta gamma-emitting nuclides should apply independently.

b As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

c Measurements of average contaminant should not be averaged over more than 1 m^2. For objects of less surface area, the average should be derived from each such subject.

d The maximum contamination level applies to an area of not more than 100 cm^2.

e The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally, and the entire surface should be wiped.

f The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/hr at 1 cm and 1.0 mrad/hr at 1 cm, respectively, measured through not more than 7 mg/cm^2 of total absorber.

While the NRC Guidelines require measurement of alpha activity for U-nat, U-235, U-238, and associated decay products, this will be supplemented in the Frankford Arsenal surveys by measurement of beta activity because of the difficulty in accurately measuring alpha activity embedded in surfaces.

9.3.2 Airborne Contaminants

9.3.2.1 Heavy Metals

Airborne concentrations of heavy metals must not exceed:

Mercury	1.6 $\mu g/m^3$
Cadmium	1.6 $\mu g/m^3$
Chromium	1.6 $\mu g/m^3$
Lead	1.5 $\mu g/m^3$

The concentrations of cadmium, chromium, and lead will be determined by atomic absorption analysis of three filter samples, utilizing Cellulose Ester (CE) air filters with 0.8-μm pore size and an air moving pump operating for 8 hours at a flow rate of approximately 1500 cc/min. Mercury concentrations will be measured by use of a mercury sniffer operating with an air flow rate of approximately 750 cc/min.

9.3.2.2 Explosives

No criteria are established for explosives in air, and no sampling and analysis is required.

9.3.2.3 Radioactive Material

Airborne concentrations of radioactive materials in gaseous effluents must not exceed the following:

Contaminant	Allowable Concentration (μCi/ml)
H-3	2×10^{-7}
Co-60	3×10^{-10}
Zn-65	2×10^{-9}
Kr-85	3×10^{-7}
Ag-110m	3×10^{-10}
Pm-147	2×10^{-9}
Po-210	7×10^{-12}
Ra-226	2×10^{-12}
Th-230	8×10^{-14}
Th-nat	2×10^{-12}
U-nat	5×10^{-12}
U-238	3×10^{-12}

Interpretations provided as footnotes to 10 CFR 20, appendix B, will be used. Concentrations of radioactive materials in gaseous effluents are to be averaged on a monthly basis.

9.3.3 Water Contaminants

9.3.3.1 Heavy Metals

Water may be released in two modes: as surface water and runoff or as effluent in the storm sewers or the sanitary sewers. The applicable regulations, in accordance with the contract, for effluents in sewers are the City of Philadelphia Wastewater Control Regulations Section B-2 (g) (2). Limits for pollutants in water entering the storm sewers are provided by the Delaware River Basin Guidelines.

Contaminant	Acceptable Concentration Sewers (mg/1)	Surface Runoff (ppm)
Mercury	0.005	0.01
Cadmium	0.1	0.02
Chromium	3 (total)	0.1 (hexavalent)
Lead	1	0.1

9.3.3.2 Explosives

No unneutralized explosive material may be released in water, either to the surface or as runoff or to the sewers (contract requirement).

9.3.3.3 Radioactive Material

Concentrations of radioactivity in water must not exceed the following:

Contaminant	Allowable Concentration (μCi/ml) Sewers	Surface/Runoff
H-3	1×10^{-1}	3×10^{-3}
Co-60	1×10^{-3}	3×10^{-5}
Zn-65	3×10^{-3}	1×10^{-4}
Kr-85 (gaseous)	-	-
Ag-110m	9×10^{-4}	3×10^{-5}
Pm-147	6×10^{-3}	2×10^{-4}
Po-210	2×10^{-5}	7×10^{-7}
Ra-226	4×10^{-7}	3×10^{-8}
Th-230	5×10^{-5}	2×10^{-6}
Th-nat	6×10^{-5}	2×10^{-6}
U-nat	1×10^{-3}	3×10^{-5}
U-238	1×10^{-3}	4×10^{-5}

Interpretations provided as footnotes to 10 CFR 20, appendix B, will be used. Concentrations in effluent released to the surface are to be averaged on a monthly basis.

9.3.4 Soil Contaminants

9.3.4.1 Heavy Metals

Sludge in sumps identified as containing heavy metals is to be removed and disposed of in an approved landfill in accordance with contract requirements.

9.3.4.2 Explosives

Acceptable cleanness of soil, relative to explosives, is established by flashing or flaming per the contract.

9.3.4.3 Radioactive Material

No broad standards for residual radioactivity in soil currently exist. NRC criteria have been developed for uranium mill sites, at which the major hazards result from exposure to gamma radiation from the daughters of radium-226 and inhalation of the daughters of radon-222. These criteria indicate that uniform contamination of soil by radium-226 to a concentration of 3 pCi/gm results in acceptable gamma-radiation and inhalation hazards. Other exposure pathways are less significant. The relative hazard of the various radioactive contaminants can be used to derive acceptable levels of soil contamination. Areas identified as containing radioactively contaminated soil will be cleaned by removal of the soil.

Successful decontamination will be demonstrated by conformance to the following radioactive concentrations:

Contaminant	Acceptable Activity (pCi/gm)
Ra-226 Th-230	3
Po-210	30
H-3 Co-60 Zn-65 Ag-110m Pm-147 Th-nat	150

These limits are consistent with the surface contamination limits presented in section 9.3.1.3.

On July 14, 1980, the Nuclear Regulatory Commission suggested that a soil action level criteria of 35 pCi/gm depleted uranium above background was applicable to the Frankford Arsenal Decontamination Program. Licence number SUB-1339 was amended to include this value.

A series of 36 uncontaminated soil samples from Frankford Arsenal and two nearby locations has shown background activity as 13 pCi/gm alpha and 15 pCi/gm beta. The acceptance limit for soil contaminated with natural or depleted uranium is therefore:

Alpha activity = 35 pCi/gm plus the average background soil alpha activity (13 pCi/gm)
= 48 pCi/gm alpha

Beta activity = 35 pCi/gm plus the average background soil beta activity (15 pCi/gm)
= 50 pCi/gm beta

9.3.5 Sumps, Sewers and Drains (Radioactive contaminants)

Based on the ANSI Standard N13.12 (August 1978) and NRC Guidelines (November 1976), the following criteria for release of sewers and drains for unrestricted use are established:

1) Drain lines and sewers that are not likely to be (or are not potentially) contaminated may be released without further consideration. This judgment must be determined from historical use information, proximity to radioactive materials areas, and analysis of material from drains and inlets and outlets of sumps.

2) Drain lines and sewers that are likely to be (or are potentially) contaminated will be surveyed at all accessible locations. These locations must be shown to be sufficiently representative of contamination in the line that it is unlikely that significantly greater contamination would exist elsewhere. Since traps might accumulate radioactive contamination, this is the reason for the NRC insistence that all traps be surveyed. The acceptance criteria are those presented for surfaces in section 9.3.1.3.

   The interior surface of a drain line should be surveyed by use of the appropriate alpha or beta probe and by smears, if possible. If this is not possible, the interior may be swabbed with a wet sponge, and the water extracted by squeezing into a container after the swabbing. The minimum amount of water needed to retrieve a good sample should be applied to the sponge, and the sponge should be vigorously swabbed against the surface of the drain line. Alternative methods of sampling water from the drain lines for determination of radioactivity may be used when more suitable. The acceptance limits are those presented in section 9.3.3.3 for water released in unrestricted areas if the drain line is to be disconnected from

the sewer and left in place, or for water in unrestricted areas if the drain line is to remain as part of the sewer system.

Portions of the drain system downstream of an acceptably clean line may be assumed to be clean also, unless traps or sumps or other features of the drain line might accumulate contamination.

If a drain line or sewer exceeds the acceptable contamination limits, it should be removed or cleaned by mechanical abrasion or chemical washes (if appropriate) until decontaminated below the limits.

In all cases, contaminated sewers and drains shall be cleaned to residual levels that are "as low as reasonably achievable."

9.4 RADIOLOGICAL DECONTAMINATION

9.4.1 Buildings

The 12 buildings identified in the contract as containing radiological contaminants were decontaminated. Certification of the post-decontamination radiological surveys of each of the buildings verifying that the results met the cleanness criteria specified in sections 9.3.1.3 (for surfaces) and 9.3.5 (for building interior drains) is presented in the following documents:

Building	Report
46	N505SRR000018
64	N505SRR000013
108	N505SRR000012
121	N505SRR000008
149	N505SRR000017
150	N505SRR000016

Building	Report
201	N505SRR000010
210	N505SRR000011
227B	N505SRR000009
316	N505SRR000015
518	N505SRR000014
521	N505SRR000019

Appendix A of the contract (i.e., the BCL Final Report) identified nine buildings where spotty rad contamination was identified on the roofs. Decontamination was conducted (only a very minor effort was required), and certification that the roof surfaces meet the surface cleanness criteria listed in section 9.3.1.3 is presented in document N505SRR000024.

NRC toured the decontaminated buildings and verified the Rockwell post-decontamination rad survey results presented in the above reports. Documentation to this effect was sent to USATHAMA by NRC.

9.4.2 Outside Areas

Cleanup of the four outside areas was accomplished by removing the contaminated materials which were subsequently packaged and shipped to Barnwell for burial. Certification that the final rad survey results on these areas met the soil cleanness criteria presented in section 9.3.4.3 is presented in report N505SRR000020. NRC verified these results, and documentation to this effect was sent to USATHAMA by NRC.

9.4.3 Sumps

After removal of the sludge and high-pressure rinsedown of the 42 sumps identified in the contract as being rad contaminated, a rad survey was conducted. The results of the survey showed that the sumps met the cleanness criteria listed in section 9.3.5. Certification of this finding is presented

in report N505SRR000022. NRC verified these findings, and documentation to this effect was sent to USATHAMA by NRC.

9.4.4 Sewers

The 15 sewers identified in the contract as being rad contaminated were surveyed and found to meet the cleanness criteria listed in section 9.3.5. No decontamination work was required. Certification of these findings is presented in report N505SRR000021, and these results were subsequently verified by NRC. Documentation to this effect was sent to USATHAMA by NRC.

9.4.5 Vents

The rad-contaminated vents in the four buildings identified in the contract (those that were still in place when Rockwell moved on site) were removed, packaged, and shipped to Barnwell for burial. This is certified in report N505SRR000028. NRC verification was accomplished by NRC overchecks on the buildings (see section 9.4.1).

9.5 CLEANUP OF EXPLOSIVES RESIDUES

Cleanup of explosives residues in the eight buildings,* six sumps, and three vents**identified in the contract as contaminated with explosives residues was accomplished by flaming. This satisfied the cleanness criteria presented in section 9.3.1.2. In addition, TLC samples were taken and analyzed to provide additional assurance that any explosives residues had been cleaned up. Certification of the TLC samples for buildings are contained in the following reports:

*Originally 14 buildings were identified in the contract. This was subsequently revised downward to eight by USATHAMA direction in the Army's letter of July 16, 1980.

**Only one vent was found by Rockwell (building 316, range C). The vents in the other two buildings had been removed prior to Rockwell moving onto the site.

Building	Report
68	N505TI000044
69	N505TI000040
151	N505TI000041
151A	N505TI000043
214	N505TI000046
214A	N505TI000042
222	N505T0000059
521	N505TI000039

Certification that the sumps are free of any explosives residues (based on water samples taken from the sumps after flaming) is contained in report N505TI000062. Certification of flaming of the building 316, range C vent (subsequently packaged and shipped to Barnwell as rad waste) is presented in document N505TI000057.

9.6 CLEANUP OF HEAVY METAL RESIDUES

9.6.1 Buildings

Certification that the 135 buildings identified in the contract met the cleanness criteria for airborne heavy metal levels is presented in document N505TI000065 along with certification that the buildings were painted in accordance with contract requirements.*

9.6.2 Sumps

Certification that the sumps associated with the 23 buildings (identified in the contract as sumps being contaminated with heavy metals) met the cleanness criteria listed in section 9.3.3.1 is presented in document N505TI000062.**

*Painted to a 6-foot height with paint containing less than 0.06 weight percent lead.

**Five of the sumps associated with building 046, three of the sumps associated with building 119, and one sump associated with building 219 were above cleanness criteria limits. These sumps were decommissioned by backfilling with concrete.

9.6.3 Vents

Certification that the vents sampled in the 32 buildings (identified in the contract as containing heavy metal contamination) met the airborne acceptance criteria listed in section 9.3.2.1 is presented in document N505TI000063.

9.7 WASTE DISPOSAL

Wastes generated as a result of the decontamination program were disposed of in accordance with the applicable Federal, state, and local regulations. The detailed disposal records and associated approvals are presented in Rockwell document N505TI000064. Table 2 summarizes the waste disposal actions.

Table 2. Summary of Waste Disposal Actions

Waste Description/Source	Disposal Site	Hauler
Rad waste from all buildings (except 46), outside areas and the 316 sewer	Barnwell, South Carolina	Tri-State Motor Transit Arlington, VA
Rad waste from building 46	Beatty, Nevada	Tri-State Motor Transit Arlington, VA
Sump water	City of Philadelphia sanitary sewer system	—
Sump sludge	Lyncott Corp. Landfill New Milford, PA	Eldredge, Inc. Glen Mills, PA
400 Area rubble (excluding asbestos)	Reclamation Landfill (Pennsauken, NJ) and City Landfill, 80th & Penrose, Philadelphia, PA	Robert Hawthorne, Inc. Philadelphia, PA
400 Area asbestos (friable and transite)	Kinsley Landfill Deptford, NJ	Eastern Industrial Corp. Deptford, NJ
Heavy metals from building cleanup (paint flakes)	GROWS Landfill Morrisville, PA	

10. SUMMARY AND CONCLUSIONS

In summary, the decontamination and cleanup of Frankford Arsenal has been completed to the requirements of contract DAAK11-79-C-0135 between the Department of the Army and Rockwell. Operations were conducted in accordance with Army-approved procedures, and post-cleanup data indicate that the approved cleanness criteria for the contract-identified facilities and contaminants have been satisfied. The contract workscope was completed 1 month ahead of the 17-month contract deadline. Cost growth on this CPFF contract (approximately 25% of the original contract value) was directly associated with the unanticipated extent of radiological contamination uncovered during the phase III operations.

Several important conclusions are drawn from this experience:

1) Most of the radiological contamination at the Arsenal was discovered as the actual decontamination work progressed. Contamination was found behind and underneath building structures (e.g., the target plates in the 316 and 521 firing ranges, the flooring in 46, etc.) where no amount of the presurvey effort could ever have mapped the extent of the contamination. The resulting "search and destroy" operation conducted in the contract-identified buildings was the only viable option available to accomplish the radiological decontamination to the levels required for release of the Arsenal for unrestricted use. Future programs of this type should be viewed in light of this experience.*
2) The soil cleanness criterion generated during the Frankford program (and subsequently approved by the NRC as a guideline for the program) provides a solid precedent for future cleanup jobs.

*A balance must be struck between the costs of the survey and the cost of the decontaminated work. For Frankford this ratio was approximately 10% (survey to decontamination costs).

3) The solid fuel approach for destroying explosives residues in the sumps is a safe and effective method for dealing with explosives cleanup in such structures.

4) The approach used for the cleanup of explosives residues in the 400 area — which was somewhat spectacular inasmuch as the Arsenal is located in a highly populated and industrialized part of Philadelphia — was totally vindicated from a personnel safety standpoint. Preburn coordination with the city, local civic, and community action groups and the media was extremely effective in moving forward with this approach.

5) Obtaining state approval for disposal of the (some-what innocuous) sump sludges, including the time required for the necessary analyses of the sludges, took nearly 7 months of concentrated effort. Even more lengthy approval cycles are to be expected in the future now that the Resources Conservation and Recovery Act (RCRA) rules are in force.

APPENDIX
SUPPORTING DOCUMENTATION

Table A1 shows the program document tree. The documents contain the detailed planning procedures, certifications, and supporting technical details pertinent to the Frankford Arsenal decontamination and cleanup program.

Table A1. Program Document Tree
(Sheet 1 of 5)

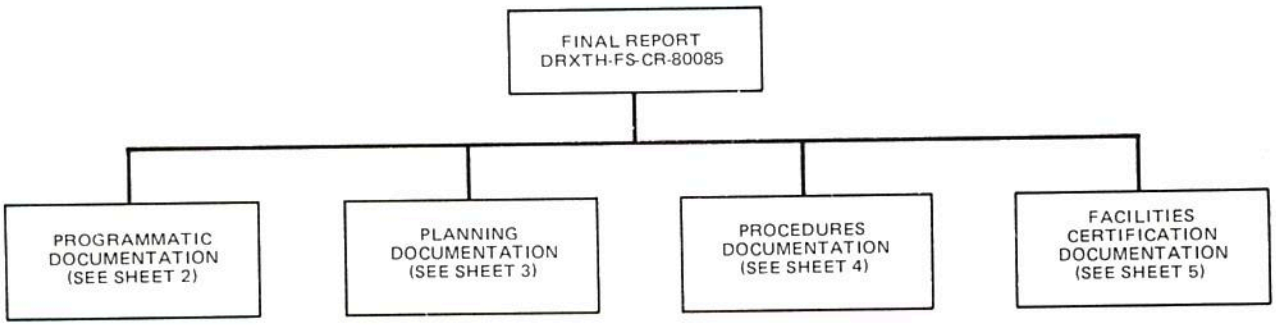


Table A1. Program Document Tree
(Sheet 2 of 5)

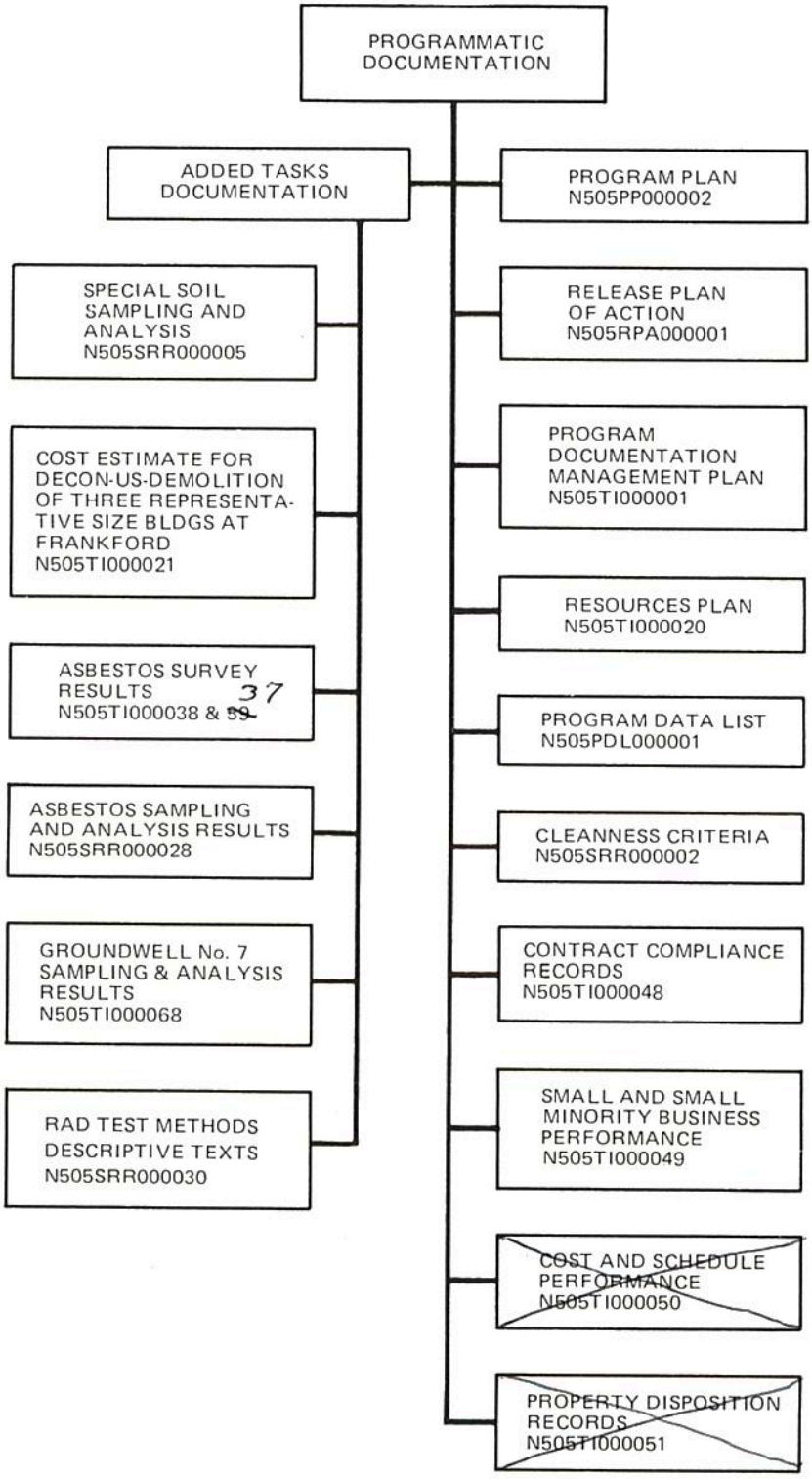


Table A1. Program Document Tree
(Sheet 3 of 5)

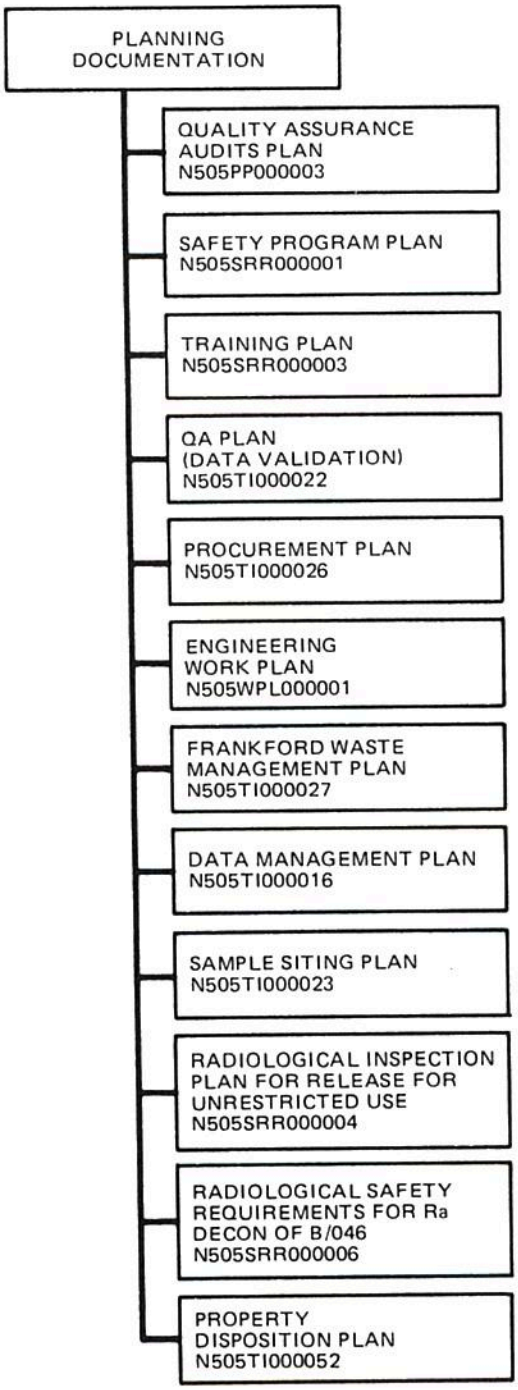


Table A1. Program Document Tree
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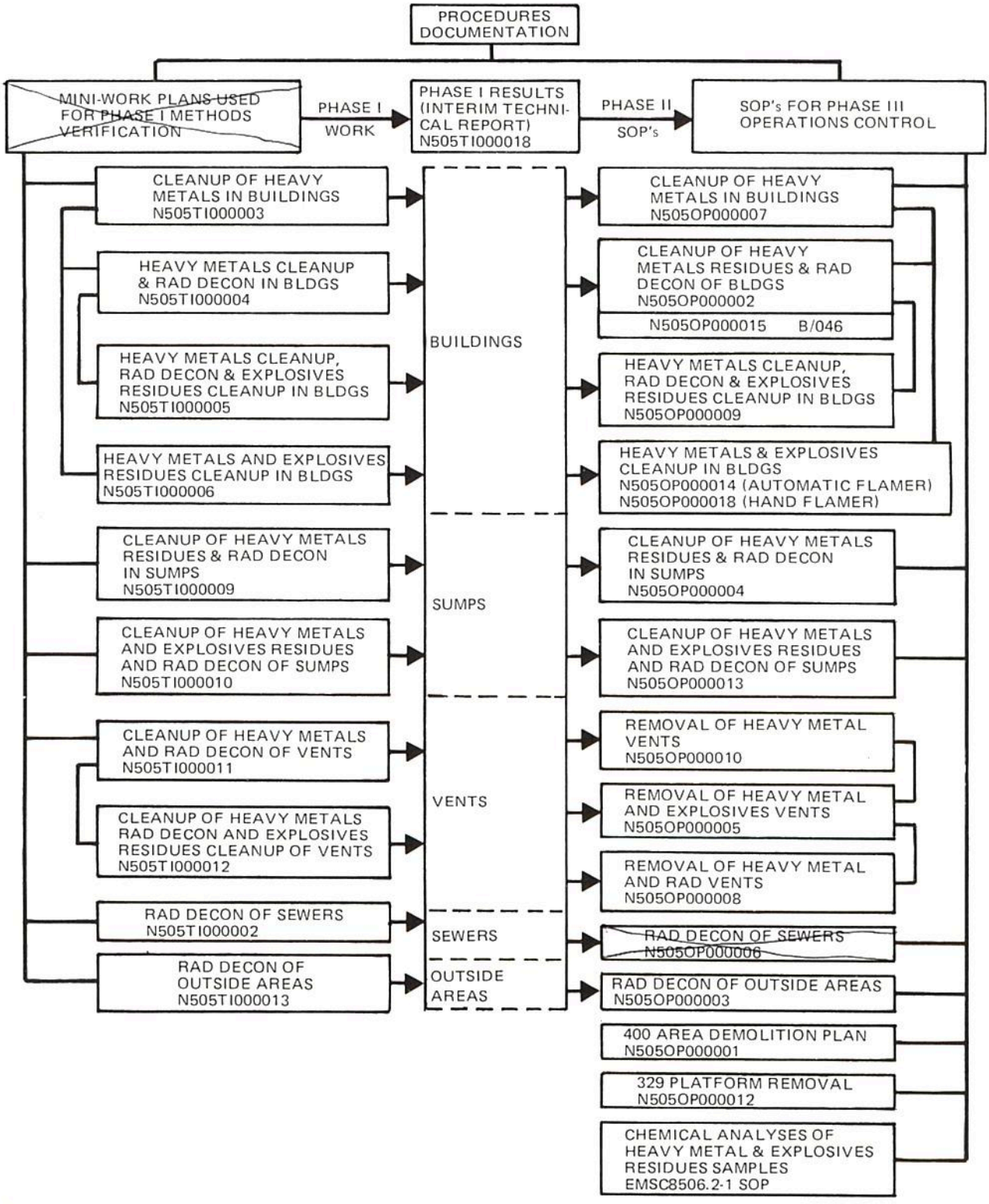
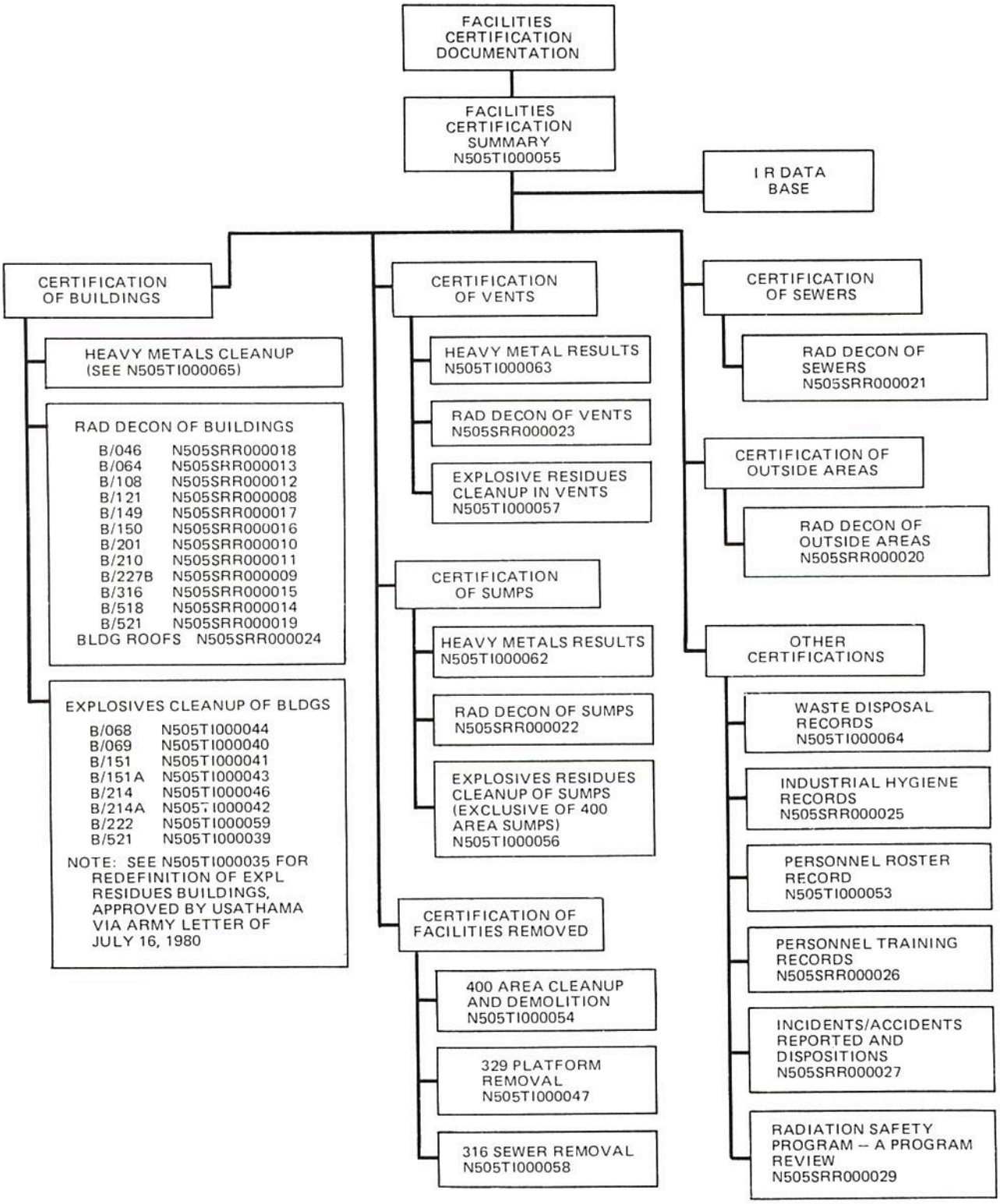


Table A1. Program Document Tree
(Sheet 5 of 5)



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